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United States
Department of
Agriculture

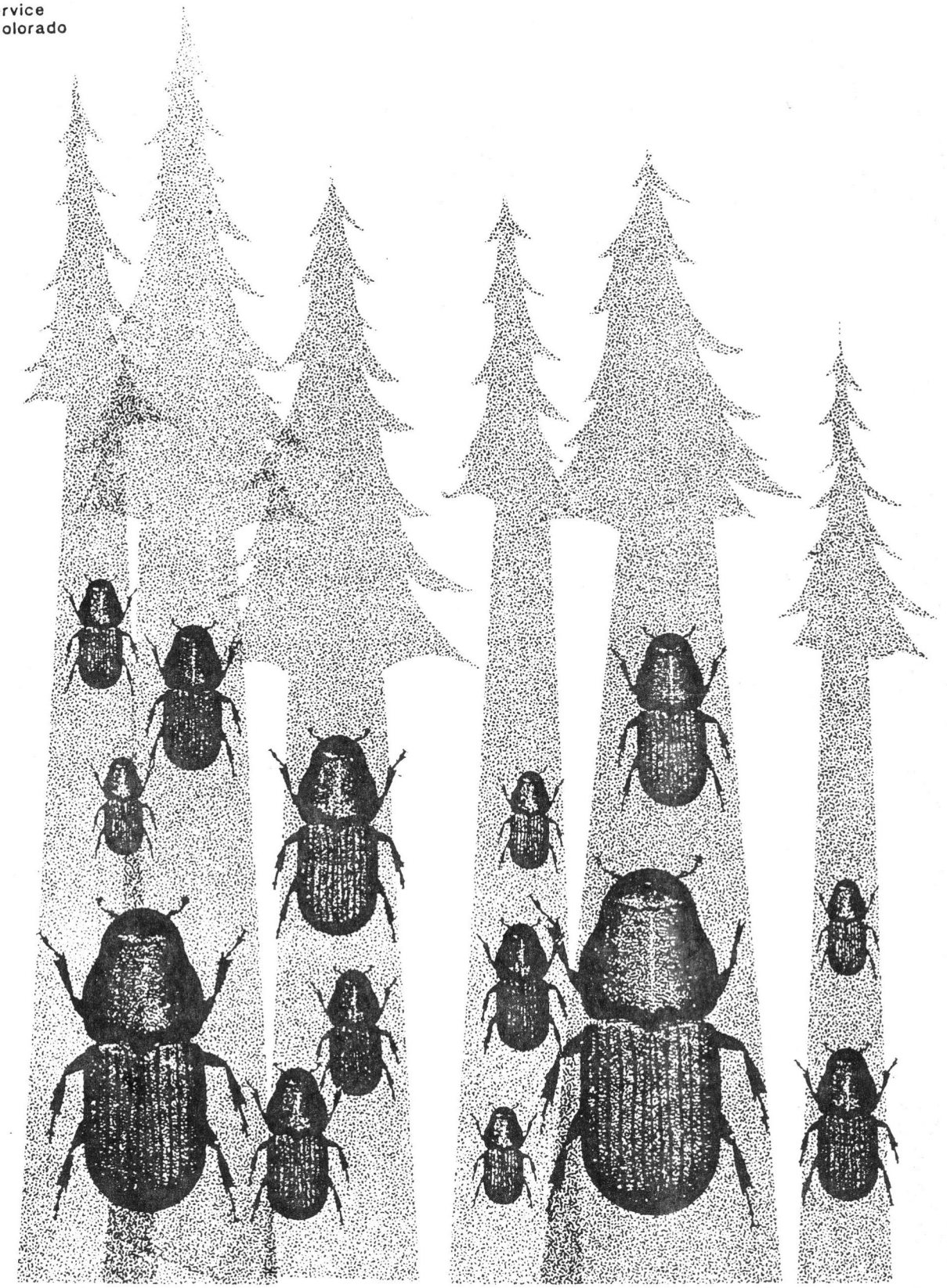
Prepared by

Timber,
Forest Pest,
& Cooperative
Forestry
Management

Forest Service
Denver, Colorado

ANNOTATED BIBLIOGRAPHY

Mountain Pine Beetle



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KAW ALS DHB

Reply to: 3400 Forest Pest Management

Date: JAN 6 1986

Subject: Annotated Bibliography

To: Colleagues

Enclosed is a bibliography of the mountain pine beetle. Where authors' abstracts are available, they are included. The intent is to produce a complete annotated bibliography which can be updated yearly. A citation preceded by an asterisk (*) indicates that the publication is not currently available in this office. We would appreciate your staff's review of the bibliography and their assistance in the following:

1. Add any citations they have authored which are not listed.

2. Provide two (2) copies of publications they have authored which are preceded by an asterisk (*) as well as new citations from (1) above.

KAW

3. If so inclined, provide a brief abstract of papers they have authored where needed.

4. Indicate whether they could provide publications preceded by an asterisk (*) authored by others (particularly old unpublished reports).

I will coordinate with WESTFORNET to insure that they have copies of all available publications listed in the bibliography. WESTFORNET will then serve as the distribution center for scientists requesting listed publications.

Hope to see you in Victoria in March.

Gene Lessard

GENE LESSARD
Supervisory Entomologist

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ANNOTATED BIBLIOGRAPHY

MOUNTAIN PINE BEETLE, *DENDROCTONUS PONDEROSAE*, HOPKINS (COLEOPTERA: SCOLYTIDAE)

Gene Lessard

Meg Hansen

Mary Lu Eilers

TECHNICAL REPORT R2-35

January 1986

Timber, Forest Pest, and Cooperative Forestry Management
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Amman, G. D. 1969. Mountain pine beetle emergence in relation to depth of lodgepole pine bark. USDA For. Serv. Res. Note INT-96, 8 pp.

ABSTRACT

Phloem thickness is one of the important factors affecting mountain pine beetle (*Dendroctonus ponderosae* Hopkins) survival in lodgepole pine (*Pinus contorta* Dougl.). Emergence holes made by adults which completed larval development within the trees were counted on two 6- by 6-inch areas of bark on each tree killed by the mountain pine beetle on twenty 1/10-acre plots. Various tree, stand, and site factors were also measured. Emergence holes ranged from none in bark 0.06 inch thick to an average of 120 per square foot where the bark was 0.18 inch thick. Emergence holes were most closely correlated with bark depth, and varied with stand density and plot elevation. The greatest proportion of thick-barked trees was in the large diameter classes.

Amman, G. D. 1970. Prey consumption and variations in larval biology of *Enoclerus sphegeus* (Coleoptera:Cleridae). Can. Entomol. 102:1374-9.

ABSTRACT

Larvae of *Enoclerus sphegens* Fabricius (Coleoptera: Cleridae) were separated into three groups for study. Throughout their development, the larvae in each group were fed mountain pine beetle larvae, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), of a specific size (small, medium, or large). Clerid larvae fed small *D. ponderosae* larvae generally completed three stadia, while the other two groups, which were fed medium-sized and large prey, respectively, usually passed through two larval stadia. The number of stadia a larva would have was determined by the amount of food consumed during the first stadium. The feeding period of larvae given small prey was considerably longer than that of those fed medium-sized or large beetle larvae, but the prepupal period was much shorter. The head capsules of second-instar larvae that passed through two stadia were distinctly wider than those of second-instar larvae that completed three stadia.

Amman, G. D. 1972. Some factors affecting oviposition behavior of the mountain pine beetle. Env. Entomol. 1:691-5.

ABSTRACT

Four factors that affect oviposition behavior of *Dendroctonus ponderosae* Hopkins in lodgepole pine, *Pinus contorta* Douglas, were investigated. These were distance between egg galleries, size of the female, phloem thickness, and temperature.

The average number of eggs oviposited per inch of gallery increased with increases in each of the 4 factors. The average number of eggs oviposited per day also increased with increases in each factor except that the effect of distance between galleries was not investigated. The rate of gallery construction increased only with an increase in temperature; it was unaffected by size of female and phloem thickness. Again the effect of distance between galleries was not investigated.

Amman, G. D. 1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. J. Econ. Entomol. 65:138-40.

ABSTRACT

The effects of phloem thickness of lodgepole pine, *Pinus contorta* Douglas, and number of inches of egg gallery of *Dendroctonus ponderosae* Hopkins on brood production of the beetle were investigated in laboratory studies. Brood production ranged from an average of 16 beetles for phloem 0.09 inches thick to 91 beetles for phloem 0.23 inches thick. Brood production ranged from about 3 beetles for 10 inches of egg gallery to 130 beetles for 174 inches of egg gallery. When food supply limited production, numbers of emerging brood adults increased linearly with phloem thickness. When food supply did not limit production, numbers of emerging brood adults increased exponentially with an increase in inches of egg gallery.

Amman, G. D. 1972. Prey consumption and development of *Thanasimus undulatus*, a predator of the mountain pine beetle. Env. Entomol. 1:528-30.

Amman, G. D. 1973. Population changes of the mountain pine beetle in relation to elevation. Env. Entomol. 2:541-7.

ABSTRACT

Dendroctonus ponderosae Hopkins was studied in lodgepole pine, *Pinus contorta* Douglas, at 4 elevations between 1923 and 2750 m in northwestern Wyoming. The beetle had a 1-year life cycle at 1923 and 2130 m. At 2450 m, part of the population completed a generation in one year, but the remainder required two years. Two years usually were required to complete a generation at 2573-2750 m. Life tables showed high mortality rates and declining populations at the 3 highest elevations, in contrast to high survival rates and increasing populations at the lowest elevation. Cool temperatures at high elevations delayed development, so the beetle overwintered in stages that were particularly vulnerable to winter temperatures. The conclusion is that mountain pine beetle populations are regulated by weather at high elevations.

* Amman, G. D. 1975. Insects affecting lodgepole pine productivity. In D. M. Baumgartner (ed.). Management of lodgepole pine ecosystems. Wash. St. Univ, Coop. Ext. Serv., Pullman, Vol. 1, pp 310-41.

Amman, G. D. 1975. Abandoned mountain pine beetle galleries in lodgepole pine. USDA For. Serv. Res. Note INT-197. 6 pp.

ABSTRACT

During the fall of 1974, 129 galleries of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in 32 recently attacked lodgepole pines (*Pinus contorta* var. *latifolia* Engelmann) were examined to determine incidence of "pitching out." With one possible exception, galleries containing no females (33 percent) had been abandoned; females had not been pitched out. Small trees generally had a higher proportion of abandoned galleries, and these were usually longer than those in large trees. Low occurrence of males, which probably resulted in low incidence of fertilization in the attacking population on individual trees, is believed to be the factor responsible for gallery abandonment. Fertilized females constructed galleries and oviposited regardless of attack density.

Amman, G. D. 1976. Integrated control of the mountain pine beetle in lodgepole pine forests. Proc. XVI IUFRO World Cong., Div. II, Norway 1976 pp. 439-46.

ABSTRACT

Regulation of mountain pine beetle *(Dendroctonus ponderosae* Hopkins) populations in lodgepole pine *(Pinus contorta* var. *latifolia* Engelmann) forests is based on insect-host interactions, and land-use objectives. The mountain pine beetle periodically kills most of the trees of large diameter in a stand. The beetle selects the largest trees where phloem, the food of the larvae, is usually thick and beetle survival is high. Periodicity of infestations is related to rapidity with which a stand of trees grows into diameter-phloem distributions conducive to population buildup.

Forest management practices consisting of clear or partial cuttings are recommended in commercial forests. Particularly susceptible stands can be converted to other tree species, or harvest rotations can be shortened so that trees of small diameter that meet certain product requirements can be cut before the trees reach sizes and phloem thickness susceptible to beetle attack. Regulation of the beetle is not recommended in recreational and noncommercial forests. In these forests, lodgepole pine will be succeeded by spruce and firs. These species will fulfill requirements, of recreation, watershed, and other values as well as lodgepole pine. Chemical insecticides can be used to protect trees of high value from beetle infestation in campgrounds and around home sites.

* Amman, G. D. 1977. The role of the mountain pine beetle in lodgepole pine ecosystems: impact on succession. In W. J. Mattson (ed.). The role of arthropods in forest ecosystems. Proc. 15th Internat. Cong. Entomol., pp 3-18.

Amman, G. D. 1978. Biology, ecology, and causes of outbreaks of the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark, D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 39-53.

ABSTRACT

The mountain pine beetle *(Dendroctonus ponderosae* Hopkins) typically produces one generation per year. The year begins with adults infesting trees and introducing blue-stain fungi into them in July and early August. Eggs are laid singly in niches on alternative sides of the vertical egg galleries. Larvae hatch and feed in the phloem, usually at right angles to the egg gallery. Larvae overwinter, then complete development in the spring. Pupation occurs in chambers made in the bark and outer sapwood. During endemic periods, beetles infest weakened and injured trees and those

infested by other species of bark beetles. Epidemics appear to start when enough such trees are in proximity and emerging brood adults converge and infest a common tree or group of trees of medium to large diameter and medium to thick phloem. The beetle shows a strong preference for such trees, and its survival usually is best in them. Tree stress is not necessary for the start of epidemics. Stand characteristics associated with epidemics are 1) trees more than 80 years old, 2) average tree diameter more than 20 cm (8 inches), 3) a substantial number of trees in the stand with diameter at breast height of 30 cm (12 inches) or more and phloem 0.25 cm (0.10 inch) thick or more, and 4) stand site at an elevation where temperatures are optimum for brood development.

Amman, G. D. 1980. Incidence of mountain pine beetle abandoned galleries in lodgepole pine. USDA For. Serv. Res. Note INT-284, 6 pp.

ABSTRACT

Individual lodgepole pines have lower densities of attack by mountain pine beetles and a higher percentage of abandoned egg galleries in stands where beetle populations are low rather than high. Most trees contain some galleries having live beetles, as well as abandoned galleries. Females from galleries likely to be abandoned have been mated, discounting the unfertilized female as a reason for gallery abandonment. The amount and quality of blue-stain fungi carried by the beetle may influence success of gallery construction.

Amman, G. D. 1982. The mountain pine beetle - identification, biology, cause of outbreaks and entomological research need. In D. M. Shrimptom (ed.). Proceedings of the Joint Canada/USDA Workshop on mountain pine beetle related problems in western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, p. 7-12.

Amman, G. D. 1982. Characteristics of mountain pine beetle reared in four pine hosts. Env. Entomol. 11:590-3.

ABSTRACT

Mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), obtained from naturally infested lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were reared in four common hosts: ponderosa pine, *P. ponderosa* Lawson; western white pine, *P. monticola* Douglas; whitebark pine, *P. albicaulis* Engelmann; and lodgepole pine. Emerging beetles were collected daily, counted, and sexed, and pronotal width was measure.

Significant differences in brood production, size of female beetles, and developmental rate, but not sex ratio, occurred among hosts. Differences were not all associated with the same species of tree. However, the results indicate that, overall, lodgepole pine is the poorest, and ponderosa pine is the best, of the four hosts for mountain pine beetle.

Amman, G. D. 1983. Strategy for reducing mountain pine beetle infestations with ponderosa pine trap logs. USDA For. Serv. Res. Note INT-338, 3 pp.

ABSTRACT

Mountain pine beetle were strongly attracted to ponderosa pine logs in decks. Of 283 logs cut in June and July and placed in decks, 74.9 percent became infested by mountain pine beetles. These observations suggest that ponderosa pine trap logs cut before beetle flight could attract a large proportion of beetles in a stand. The infested logs then could be removed to reduce the beetle population in the area.

Amman, G. D. 1984. Mountain pine beetle (Coleoptera: Scolytidae) mortality in three types of infestations. Env. Entomol. 13:184-91.

ABSTRACT

Populations of mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), in lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were sampled at three heights within trees in endemic, epidemic, and postepidemic infestations. Eight mortality factors were evaluated: competition within and between broods, parasites, predators, pathogens, winter temperature, drying of the phloem, pitch, and unexplained mortality. Beetle survival was significantly greater ($P < 0.01$) in endemic (3.7%) than in epidemic (1.4%) and postepidemic (0.5%) infestations. Survival did not differ ($P > 0.05$) by height in trees. Parasites and predators accounted for 8, 33, and 4% of total mountain pine beetle losses in endemic, epidemic, and postepidemic infestations, respectively. *Medetera* (13%) and woodpeckers (15%) accounted for the greatest amount of predation, and this occurred during epidemic infestations. Most parasites and predators showed the typical density-dependent response. Clerids were the single exception, taking a greater proportion of beetles in endemic infestations, thus suggesting a role by clerids in keeping mountain pine beetle populations at an endemic level. However, clerids accounted for only 0.9% of beetle losses.

Amman, G. D. 1985. The beetle: behavior, biology, and life cycle. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp 2-7.

Amman, G. D. and B. H. Baker. 1972. Mountain pine beetle influence on lodgepole pine stand structure: an analysis of treated and untreated stands. J. For. 70:204-9.

ABSTRACT

Efforts to control populations of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in lodgepole pine (*Pinus contorta* Dougl.) were evaluated from tree diameter distributions within treated and untreated stands. Beetle populations, where infestation period was complete, declined in approximately the same number of years, and lodgepole pine survival in the two types of stands was comparable. However, suppression measures did slow the rate of tree mortality in two stands still under attack. Mixed stands of up to 36 percent trees of other species were proportionally as susceptible to beetle infestation as those having less than 10 percent trees of other species. Survival increased with elevation, apparently because of adverse effect of temperature on beetles.

Amman, G. D. and W. E. Cole. 1983. Mountain pine beetle dynamics in lodgepole pine forests. Part II. Population dynamics. USDA For. Serv. Gen. Tech. Rept. INT-145, 59 pp.

ABSTRACT

Much of this work is original research by the authors. However, published literature on the taxonomy, biology, and population dynamics of the beetle are reviewed primarily as they occur in epidemic beetle populations in lodgepole pine forests. Lodgepole pine tree characteristics such as size and phloem thickness have a strong influence on beetle survival, size, sex ratio, and genotype. Of the many mortality factors acting upon the beetle population alone or in combination, none regulate the population before severe damage occurs to stands of lodgepole pine. These findings demonstrate that the mountain pine beetle is food regulated.

Amman, G. D., B. H. Baker and L. E. Stipe. 1973. Lodgepole pine losses to mountain pine beetle related to elevation. USDA For. Serv. Res. Note INT-171, 8 pp.

ABSTRACT

Mortality caused by the mountain pine beetle was related inversely to elevation and ranged from less than 1 to 17 percent of the lodgepole pine trees 4 inches d.b.h. and larger. Mortality of trees 9 inches d.b.h. and larger (those most often infested by mountain pine beetle), ranged from 2 percent of the stems or 0.8 percent of the basal area at the highest elevation to 36.5 percent of the stems or 36 percent of the basal area at the lowest elevation. Climate probably is the single most important factor accounting for variation in mortality of lodgepole pine at the different elevations because of its effect on the biology of the beetle.

Amman, G. D. and M. D. McGregor. 1985. Assessing stand hazard and risk: hazard rating and predicting tree loss in unmanaged stands. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 29-30.

Amman, G. D., M. D. McGregor, D. B. Cahill and W. H. Klein. 1977. Guidelines for reducing losses of lodgepole pine to mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA For. Serv. Gen. Tech. Rept. INT-36, 19 pp.

ABSTRACT

These guidelines are based on ecological relationships of the beetle and its host. They are applicable to unmanaged stands. In these stands, beetles show a strong preference for lodgepole pine of large diameter and 80 years of age or older. Stands at low elevations suffer the greatest losses to beetle infestation. At low elevations, climate is optimal for brood survival; the cool climate of high elevations has an adverse effect on survival of the beetle. These factors--tree diameter, tree age, and stand location--are used to predict stand risk to beetle infestation.

Measures can be taken to prevent or reduce losses to the beetle. Where timber production is the primary use of the land, large high-risk trees can be removed by partial cutting techniques. However, patch cutting or clearcutting should be used where most trees are in large-diameter classes and in stands where residual trees would not be numerically adequate nor physically vigorous should partial cutting techniques be used. Essentially, a "do nothing" policy is recommended where recreation values predominate or where noncommercial forests exist. Trees of high value in campgrounds, picnic areas, and near summer and permanent homesites can be protected with chemical sprays that prevent successful beetle infestation.

* Amman, G. D., M. D. McGregor, K. E. Gibson and S. Dubreuil. 1984. Demonstration of the effectiveness of basal area cutting to reduce tree killing by the mountain pine beetle in ponderosa pine, Crow and Cheyenne Reservations, Montana, 1984. USDA For. Serv., Int. For. and Range Exp. Sta., Ogden, UT, 8 pp.

Amman, G. D. and V. E. Pace. 1976. Optimum egg gallery densities for the mountain pine beetle in relation to lodgepole pine phloem thickness. USDA For. Serv. Res. Note INT-209, 8 pp.

ABSTRACT

Laboratory studies were conducted to determine optimum densities of egg galleries constructed by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) phloem of different thickness. Beetle production per unit area of lodgepole pine bark occurred at egg gallery densities over 2.4 m per 30.4 cm^2 with greater production obtained from thick phloem. Beetle production began to flatten at about 2.1 m per 30.4 cm^2 in thin phloem and at 2.4 m in thick phloem. Production curves remained asymptotic to 3 m of egg gallery per 30.4 cm^2 the upper limit observed in this study. Beetle production per unit of egg gallery length was highest at the lowest gallery density in all phloem thicknesses. As expected, beetle production was greatest in thick phloem.

The largest brood adults emerged from thick phloem at all egg gallery densities. But, for thick and thin phloem alike, size declined after egg gallery densities exceeded about 1.5 m per 30.4 cm^2. Beetles were significantly smaller in thin phloem, even at the lowest gallery densities. Male survival was proportionately lower in thin phloem than in thick phloem. The smaller size of beetles and lower survival of males suggest a qualitative difference between thin and thick phloem that may be important in dynamics of mountain pine beetle populations.

Amman, G. D. and L. A. Rasmussen. 1969. Techniques for radiographing and the accuracy of the X-ray method for identifying and estimating numbers of the mountain pine beetle. J. Econ. Entomol. 62:631-4.

ABSTRACT

X-ray-exposure curves using 2 kilovoltages (kv) were developed for lodgepole pine slabs of different thickness and moisture content. X-ray exposure at 25 kv for a wood-and-bark slab containing 30% moisture varied, for example, from 4.5 milliampere minutes

(mam) for a 1.5-inch-thick slab to 20 mam for a 3-inch-thick slab. The relationship between wood-and-bark thickness and optimum exposure became increasingly curvilinear as moisture content increased. In contrast, X-ray exposure at 45 kv for wood and bark containing 30% moisture varied from 0.4 mam for a 1.5-inch-thick slab to 1.25 mam for a 3-inch-thick slab. At 45 kv the relationship between wood-and-bark thickness and exposure remained approximately linear for all moisture contents.

Identifications and estimates of numbers of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were obtained from radiographs. Radiographs obtained using an exposure of 25 kv proved to be best for identifying and determining numbers of small and medium-sized larvae. Radiographs obtained using either 25 or 45 kv could be used with about equal accuracy for identifying and estimating numbers of large larvae, pupae, and callow adults. Errors in identification and in estimating numbers of beetles from radiographs obtained using an exposure of 25 kv were less than 10% of the mean and seem acceptable for population studies of bark beetles.

Amman, G. D. and L. A. Rasmussen. 1974. A comparison of radiographic and bark-removal methods for sampling of mountain pine beetle populations. USDA For. Serv. Res. Pap. INT-151, 11 pp.

ABSTRACT

Populations of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were sampled by both radiographic and bark-removal methods in standing lodgepole pine, *Pinus contorta* Douglas. Estimates of live beetle numbers based on the two methods were comparable. However, the radiographic method is not recommended for field sampling because it is more costly and the causes of beetle mortality usually cannot be determined. In addition, beetle populations in areas radiographed were adversely affected, probably because of drying of wood and bark, which resulted in erroneous estimates of brood survival and distorted sex ratios.

Andrews, R. J. 1982. Mountain pine beetle infestation. Manning Provincial Park. Pac. For. Res. Cent., Can. For. Serv., Victoria, Pest Rept., March 1982, 3 pp.

Atkins, M. D. 1966. Behavioral variation among scolytids in relation to their habitat. Can. Entomol. 98;285-8.

ABSTRACT

Most scolytids occupy temporary habitats. Migration, therefore, forms an important part of adult behavior. Since the extent of migratory movement is positively correlated with the degree of impermanence of the species' habitat, differences in the behavior associated with migration must be expected to occur between species. Furthermore, the behavior of individuals must change in relation to changes in physiology associated with migration and reproduction. These changes have been demonstrated in laboratory studies, and the results suggest that the phenomenon of secondary attraction observed among scolytids may have evolved in conjunction with their utilization of transitory habitats.

Averill, R. D. 1978. Simulating yields from ponderosa pine stands attacked by the mountain pine beetle in the Black Hills. USDA For. Serv. (DRAFT)

Averill, R. D. 1978. Mountain pine beetle management strategy. USDA For. Serv., Rocky Mtn. Reg., Rept., 18 pp.

Averill, R. D., J. E. Gunter, C. K. Lister, and D. H. Sonnen. 1977. Guidelines for estimating the economic benefits of mountain pine beetle control projects. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-11, 30 pp.

Averill, R. D. and D. Leatherman. 1975. Post control evaluation, Estes Park, Colorado, September, 1974. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-3, 6 pp.

Averill, R. D. and D. Leatherman. 1983. Biological Evaluation. Mountain pine beetle in Grand County, Colorado - 1983. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-83-6, 7 pp.

Baker, B. H. 1968. The use of "buildup ratios" as indicators of mountain pine beetle population trends. USDA For. Serv., Int. Mtn. Reg., Rept., 6 pp.

Baker, B. H., G. D. Amman and G. C. Trostle. 1971. Does the mountain pine beetle change hosts in mixed lodgepole and whitebark pine stands? USDA For. Serv. Res. Note INT-151, 7 pp.

ABSTRACT

Lodgepole pine (*Pinus contorta* Dougl.) and whitebark pine (*P. albicaulus* Engelm.) losses attributable to the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) were compared in three study areas within two mixed species stands at high elevations. Results suggest that this beetle displays host specificity for the tree species in which it completed larval development because extensive mortality in one host species did not result in comparable mortality in an associated species.

* Ballard, R. G., M. A. Walsh and W. E. Cole. 1980. Beetle kill in lodgepole pine. Utah Sci. (Fall 1980):78-81.

Barger, R. L. 1982. Research needs: Engineering, utilization economics, socioeconomics, and fire. In D. M. Shrimptom (ed.). Proceedings of the joint Canada/USDA workshop on the mountian pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 24-28.

* Baumhofer, L. G. 1933. Bark beetle situation in the Roosevelt National Forest. USDA For. Serv.

Beal, J. A. 1939. The Black Hills beetle, a serious enemy of Rocky Mountain pines. USDA Farm. Bul. 1824, 22 pp.

Beal, J. A. 1943. Relation between tree growth and outbreaks of the Black Hills beetle. J. For. 41:359-66.

ABSTRACT

During the past decade losses of ponderosa pine resulting from the work of the Black Hills beetle have been exceptionally heavy. In an attempt to determine the cause of these outbreaks an analysis of the growth rate of trees, as affected by precipitation, was made. Although most of the outbreaks occurred during periods of deficient moisture and relatively poor tree growth, the exceptions strongly indicate that other factors are sometimes fully as important as these.

* Beal, J. A. and D. DeLeon. 1938. A study of the Black Hills beetle in Southeastern Wyoming and Central Colorado, summer of 1937. USDA For. Serv. Rocky Mtn. Sta., Fort Collins, CO.

* Bedard, W. D. 1931. New facts regarding the biology of the mountain pine beetle in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1933. Additional information concerning the biology and habits of the mountian pine beetle in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1933. The relation of parasites to mountain pine beetle control in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1937. A study of mountain pine beetle infestations in western white pine, 1936 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1937. The effect of tempering as a means of increasing cold-hardiness upon the lipid and moisture content of mountain pine beetle larvae. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1938. Preliminary report concerning the relationship between mountain pine beetle infestations and types of host materials, 1937 investigations. USDA Bur. Entomol., For. Insect Lab., Coeur d'Alene, ID.

* Bedard, W. D. 1938. Preliminary report relative to biological factors in the control of the mountain pine beetle, 1937 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1938. A study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID, 65 pp.

* Bedard, W. D. 1938. The relations of lipid and moisture content to cold-hardiness of mountain pine beetle larvae. USDA Bur. Entomol., Coeur d' Alene, ID.

* Bedard, W. D. 1938. Tree injection as a control of the mountain pine beetle in western white pine, 1938 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

Bedard, W. D. 1938. Control of the mountain pine beetle by means of chemicals. J. For. 36:35-40.

* Bedard, W. D. 1939. The relationship between mountain pine beetle infestations and types of host materials, 1938 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1939. Biological factors in control of the mountain pine beetle. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1939. A study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol, Coeur d'Alene, ID, 47 pp.

* Bedard, W. D. 1939. An investigation of the apparent effect of road construction on mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1940. A summary of four years' exploratory study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1940. Some factors influencing mountain pine beetle (*Dendroctonus monticolae* Hopk.) populations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Bedard, W. D. 1942. An experiment in fostering native insect enemies of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). USDA Bur. Entomol., Coeur d'Alene, ID.

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* Beeson, T. 1971. Testing covering with polyethylene sheeting for control of *Dendroctonus ponderosae* in Boulder County, Colorado, 1971. Colo. State For. Serv., Longmont, CO.

Bennett, D.D. 1979. Pilot survey to measure annual mortality caused by the mountain pine beetle in lodgepole pine on the Beaverhead, Gallatin and Flathead Forests in 1978. USDA For. Serv., Northern Reg., Rept. No. 79-12, 4 pp.

Bennett, D. D., W. E. Bausfield, M. D. McGregor and K. E. Gibson. 1980. Evaluation of multistage sampling techniques to measure lodgepole pine mortality caused by mountain pine beetle in Montana, 1979. USDA For. Serv., Northern Region, Rept. No. 80-13, 11 pp.

ABSTRACT

A pilot survey was conducted to evaluate the effectiveness of using multistage sampling techniques to measure annual and cumulative mortality on a State-wide basis with acceptable statistical reliability, timeliness, and cost.

Within the State of Montana, aerial surveys showed about 986,000 acres of lodgepole pine infested with mountain pine beetle. This area was stratified into three intensity classes. Initial stratification, from 1979 aerial sketchmap surveys, was followed by large-scale (1:6000) aerial photography (on a sample basis), photo interpretation, and ground truth measurements. Photo plots were selected by a systematic random process for each stratum. Ground truth plots were chosen by probability proportional to size (pps).

Estimates of 1978 attacked lodgepole pine (faders) were 11.6 million trees, representing a volume of 161.4 million cubic feet. Relative sampling errors were 9.8 and 16.5 percent for numbers of faders and volume, respectively. The total number of standing dead was 33.4 million trees, with a volume of 517 million cubic feet. The survey required 257 man-hours at a cost of $43,500.

Bennett, D. D. and M.D. McGregor. 1980. A demonstration of basal area cutting to manage mountain pine beetle in second-growth ponderosa pine. USDA For. Serv., Northern Reg. Rept. No. 80-16, 2 pp.

Berryman, A. A. 1976. Theoretical explanation of mountain pine beetle dynamics in lodgepole pine forests. Env. Entomol. 5:1225-33.

ABSTRACT

Sample data from 215 infested lodgepole pines from 11 separate locations in the United States and Canada were analyzed to determine the relative effect of the measured variables on mountain pine beetle emergence density (production). From this analysis a model was developed which expresses production as a function of attack density and basic habitat suitability. The measured variables having the most influence on basic habitat suitability were lodgepole pine phloem thickness, cortical resin canals, host resistance, and predation by woodpeckers. Host resistance was also found to influence the intensity of attack. A theoretical model was constructed to examine the relative effects of lodgepole pine phloem thickness, and resistance to attack, on the dynamics of the beetle population. Analysis indicated that mountain pine beetle outbreaks are triggered by rapid declines in stand resistance resulting from climatic disturbances, insect defoliation, etc.

Berryman, A. A. 1978. A synoptic model of the lodgepole pine/mountain pine beetle interaction and its potential application in forest management. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 98-105.

ABSTRACT

A simple graphical model is presented which displays the risk and intensity of mountain pine beetle (*Dendroctonus ponderosae* Hopkins)-caused timber mortality in terms of average stand phloem thickness, stand resistance to attack, and climate. The model provides a tool to help the forest manager understand the interaction between the beetle and the stand and, when fit to data from lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands, can be used to predict the likelihood of mountain pine beetle epidemics in real or simulated stands and to evaluate management alternatives.

Berryman, A. A., G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). 1978. Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For. Wild, and Range Exp. Sta., Univ. of Idaho, Moscow, 224 pp.

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ABSTRACT

A computer program, HAZARD, which utilizes TMIS data bases to rate susceptibility of lodgepole and ponderosa pine stands to mountain pine beetle attack is now available for use by forest managers. Use of the porgram is described herein.

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Billings, R. F. and R. I. Gara. 1975. Rhythmic emergence of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) from two host species. Ann. Entomol. Soc. Am. 68:1033-6.

ABSTRACT

Emergence of adult *Dendroctonus ponderosae* Hopkins from ponderosa pine *(Pinus ponderosa* Laws.) and western white pine (*P. monticola* Dougl.) exhibited distinct host-specific patterns under field conditions that appeared closely correlated with ambient temperatures in the latter host species but not in the former. The lower temperature threshold for beetle emergence was ca. 16°C. Diel periodicities in emergence from both host species also prevailed under conditions of constant temperature and light, providing evidence of an endogenous rhythm. Ratios of 1 male to 3 females, observed during the first week of seasonal emergence from ponderosa pine, appeared to change in favor of males as the season progressed. A more constant 1:2 male to female ratio was maintained in broods emerging from western white pine.

Billings, R. F., R. I. Gara and B. F. Hruthfiord. 1976. Influence of ponderosa pine resin volatiles on the response of *Dendroctonus ponderosae* to synthetic *trans*-verbenol. Env. Entomol. 5:171-9.

ABSTRACT

The synergistic effect of various host factors on the response of in-flight populations of *Dendroctonus ponderosae* Hopkins emerging from *Pinus ponderosa* Laws. to the aggregation pheromone *trans*-verbenol was quantified in a series of replicated field bio-assays. Synthetic formulations of *trans*-verbenol, although largely inactive alone, attracted beetles when deployed with certain host terpenes, particularly myrcene and terpinolene. Freshly extracted ponderosa pine oleoresin in combination with *trans*-verbenole as significantly more attractive to beetle populations, particularly to females, than were pheromone complexes containing single monoterpenes of the composite monoterpene fraction of oleoresin (distilled oil). When tested with *trans*-verbenol on traps without replacement, fresh resin samples lost their superior attractiveness within 1 day; paralleled those on pheromone traps baited with distilled oils. The qualitative monoterpene composition of fresh resin, however, did not appear to change with short term exposure or during the steam distillation process. In combination, these findings suggested the presence of host-produced chemical messengers other than monoterpenes in oleoresin which are disproportionately attractive to ♀ *D. ponderosae*, the host selecting sex. Analysis of resin samples by gas chromatography and mass spectrometry led to the constituent which may contribute to the superior field attractiveness of fresh resin. The need to further investigate the role of non-terpene host volatiles in bark beetle host selection is stressed.

Blackman, M. W. 1931. The Black Hills beetle (*Dendroctonus ponderosae* Hopk.). NY State Col. For. Tech. Pub. 36, Vol. 4, 97 pp.

* Blackman, M. W. 1938. Report on an examination of *Dendroctonus ponderosae* and *D. monticolae*. USDA Bur. Entomol. and Plant Quar., Washington, DC

Borden, J. H. 1982. Secondary attraction in the Scolytidae: An annotated bibliography. Simon Fraser Univ., Dept. of Bio. Sci., Pest Mgmt. Papers No. 26, 185 pp.

* Borden, J. H. and E. Stokkink. 1971. Secondary attraction in Scolytidae: An annotated bibliography. Can. For. Serv., For. Res. Lab., Victoria, B.C., Inform. Rept. BC-X-57, 77 pp.

Borden, J. H., L. J. Chong, and M. C. Fuchs. 1983. Application of semiochemicals in post-logging manipulation of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). J. Econ. Entomol. 76:1428-32.

ABSTRACT

Lodgepole and ponderosa pines, *Pinus contorta* var. *latifolia* Engelm. and *P. ponderosa* Dougl. ex. Laws., respectively, in the interior of British Columbia were baited with the semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin to induce attack by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. In one post-logging application, semiochemical baiting was effective in shifting the locus of a small infestation so that it could be cut and removed from the forest. In another application after a selective, sanitation-salvage cutting, semiochemical baiting was successful in concentrating a residual population in baited trees and trees surrounding them.

Borden, J. H., L. J. Chong, K. E. G. Pratt, and D. R. Gray. 1983. The application of behavior-modifying chemicals to contain infestations of the mountain pine beetle, *Dendroctonus ponderosae*. For. Chron. 59:235-9.

ABSTRACT

Five replicates of paired forest blocks containing lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., infested by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were chosen in the spring of 1982 in various interior British Columbia locations. Within the experimental block of each pair, one lodgepole pine every 50 m (4 trees/ha) was baited with the attractive semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin. The baiting program caused the attack in 1982 to be concentrated in and around the baited trees, whereas it was more dispersed in the control blocks. The overall ratio of 1982:1981 attacked trees was 2.5 in the baited blocks and 1.8 in the controls, suggesting that dispersal of beetles out of the baited blocks was inhibited. Baiting of trees with semiochemicals is recommended to contain infestations within prescribed boundaries when sanitation-salvage logging cannot be completed prior to mid-summer flight of emergent brood beetles.

Borden, J. h., J. E. Conn, L. M. Friskie, B. E. Scott, L. J. Chong, H. D. Pierce, Jr., and A. C. Oehlschlager. 1983. Semiochemicals for the mountain pine beetle, *Dendroctonus ponderosae*, in British Columbia: baited tree studies. Can. J. For. Res. 13:325-33.

ABSTRACT

Lodgepole pines, *Pinus contorta* var, *latifolia* Engelm., in three interior British Columbia locations were baited with six monoterpenes lone or combined, and various combinations of the beetle-produced volatiles *trans*-verbenol, *exo*-brevicomin, and 3-caren-10-ol. Trees baited with *trans*-verbenol, *exo*-brevicomin, and the monoterpene 3-carene sustained higher attack densities by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, and were surrounded by more attacked trees than trees baited with *trans*-verbenol and 3-carene or unbaited controls. Myrcene was apparently the best of six monoterpenes as synergist for *trans*-verbenol. 3-Caren-10-ol appeared to have some activity in an early test but did not prove to be an attractive pheromone in extensive studies. In a 17-ha portion of an infestation, treatment of 99 trees with 3-carene and *trans*-verbenol apparently caused a higher attack rate, resulting in 56.4% of the available green trees being attacked, as opposed to 22.3% of the available trees in the 14-ha unbaited area. These data as well as the high attack rates associated with trees which also had an *exo*-brevicomin bait suggest that semiochemicals could be used to contain *D. ponderosae* infestations and to attract beetles to lethal trap trees.

Boss, G. D. and T. O. Thatcher. 1970. Mites associated with *Ips* and *Dendroctonus* in Southern Rocky Mountains with special reference to *Iponemus truncatus* (Acarina:Tarsonemidae). USDA For. Serv. Res. Note RM-171, 7 pp.

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Brannan, C. F. 1948. Black Hills National Forest - 50th Anniversary. USDA For. Serv., Washington DC, 43 pp.

Brennan, J. A. 1982. The need for action. What is being done in the forests of Alberta and plans for the future. In D. M. Shrimptom (ed.). Proceedings of the joint Canada/USA workshop on the mountian pine beetle and related problems in Western North America. Can. For. Serv. Rept. BC-X-230, pp. 41-43.

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Burnell, D. G. 1977. A dispersal-aggregation model for mountain pine beetle in lodgepole pine stands. Res. Pop. Ecol. 19:99-106.

Cabrera, H. 1978. Phloem structure and development in lodgepole pine. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 54-63.

ABSTRACT

Thickness of phloem and presence of resin canals in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are important factors in the successful development of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) broods. Thick phloem is closely related to tree vigor, and contains three components: phloem increasement, phloem compression and phloem retention. Individual annual phloem increments make a relatively small contribution to total phloem thickness (usually less than 10%). Compression of old phloem tissue, resulting from increases in tree diameter, reduces the contribution of individual increments to phloem thickness to approximately half their original amount. Retention is the major factor affecting both the ultimate phloem thickness and the rate of change of phloem thickness. For the trees used in this study, the overall average period of phloem retention was 21.7 years, but for individual trees it may be in excess of 40 years in the lower bole. Resin canal density is a highly variable characteristic in lodgepole pine, but overall, densities are

usually higher in the upper parts of the tree. Resin canal density may be a useful indicator of relative tree resistance to bark beetle attack: however, research on other pine species indicates that even short-term environmental stress may result in a substantial temporary reduction in resistance.

Cahill, D. B. 1960. The relationship of diameter to height of attack in lodgepole pine infested by mountain pine beetle. USDA For. Serv. Res. Note INT-78, 4 pp.

Cahill, D. B. 1971. Biological Evaluation. Mountain pine beetle. Black Hills National Forest, Northern Black Hills, Lead and Deadwood Area, South Dakota. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-17, 4 pp.

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Cahill, D. B. 1973. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-20, 3 pp.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Owl Mountain, North Park District, Routt National Forest, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-8, 1 p.

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Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Colorado Front Range, Arapaho and Roosevelt, Pike and San Isabel National Forests, and Rocky Mountain National Park, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-22, 2 pp.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, State and private land, South Pass City-Atlantic City, Wyoming, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-25, 3 pp.

Cahill, D. B. 1976. Biological Evaluation. Mountain pine beetle. Bighorn Front Range, Bighorn National Forest, BLM, State and private land, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-5, 4 pp.

Cahill, D. B. 1977. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming, Black Hills National Forest and surrounding Federal, state and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-5, 3 pp.

Cahill, D. B. 1978. Cutting strategies as control measure of the mountain pine beetle in lodgepole pine in Colorado. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 188-91.

ABSTRACT

Efforts to suppress mountain pine beetle, (*Dendroctonus ponderosae* Hopkins) epidemics in Colorado have been carried out since the early 1900s using various methods of treating or removing beetle populations. These methods have slowed the rate of annual tree losses, but have done little to reduce total tree mortality over the course of an infestation, or to reduce the susceptibility of the stands to additional beetle attack. Based on recent research findings that demonstrated the importance of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) phloem thickness and diameter in mountain pine beetle epidemices, stands in the Middle Park area of Colorado were cut using strategies to reduce stand susceptibility to beetle attack. Partial cutting and clearcutting, combined with the logging of infested trees, were used to reduce the inventory of larger-diameter trees. Other factors considered were dwarf mistletoe, comandra rust and visual management concerns. Losses in partial-cut areas have been reduced to 1 to 2 percent of the residual trees, whereas in unmanaged stands 39 percent of the trees have been lost.

Cahill, D. B. and D. W. Johnson. 1976. Biological Evaluation. Rawlins District, Bureau of Land Management, Green Mountains, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-12, 10 pp.

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Carey, P. P. and W. R. Wilcox. _____. Disaster to opportunity. Colo. State For. Serv. Leafl.

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Carlson, R. W. and W. E. Cole. 1965. A technique for sampling populations of the mountain pine beetle. USDA For. Serv., Res. Pap. INT-20, 13 pp.

ABSTRACT

Objectives of this study were: (1) to determine the most satisfactory sample size and sampling location on a tree, and (2) to develop a sampling technique based on optimum size and location of sampling areas. Three variables (besides size and shape of sample unit) in the development of beetle populations were considered: density of attack, length of egg gallery, and brood density at late larval stage.

Carter, S. W., Jr. 1978. Potential impacts of mountain pine beetle and their mitigation in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 27-36.

ABSTRACT

The results of a project to prepare guidelines and prescribe treatment for infested lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands in the Umatilla and Wallowa-Whitman National Forests in northeastern Oregon are used to illustrate the potential impacts of a mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreak on all forest resources. Resources considered are timber, fisheries and wildlife, water, soils, recreation and esthetic value. Guidelines to mitigate the effects on these were developed with respect to the treatment selected, a three-phase harvest program over a 21-year period. This management plan was selected over no action, a two-phase harvest program over a 14-year period, and a two-phase harvest program over a 22-year period as best meeting the over-all management objectives.

Carter, S. W., Jr. 1982. A case study. Impacts of mountain pine beetle and their mitigation in lodgepole pine forests. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv., Rept. BC-X-230, pp. 65-76.

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ABSTRACT

The male and female reproductive organs of the mountain pine beetle, *Dendroctonus monticolae* Hopk. are described, and interpretations given for functions of the parts on the basis of activity during mating, sperm transfer, egg formation and ovulation. Some morphological changes of the reproductive organs during the adult life cycle are also noted.

Three pairs of accessory glands associated with spermatophore production are evident in the male beetle. One of these was previously termed the seminal vesicles. A complex musculature operates the male genital organ during copulation. The female organs have four telotrophic ovarioles with a posterior calyx region that has a possible secretory function. Evidence indicates that organs previously termed "colleterial glands" have a digestive and reabsorbing function. The bursa copulatrix may be more closely allied with the function of the accessory glands than with the mating process. Parts of the spermatheca have been more precisely defined according to function.

Chansler, J. F., D. B. Cahill and R. E. Stevens. 1970. Cacodylic acid field tested for control of mountain pine beetles in ponderosa pine. USDA For. Serv. Res. Note. RM-161, 3 pp.

ABSTRACT

In an operational-scale field test, cacodylic acid (dimethylarsenic acid) was highly effective in preventing brood development of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in ponderosa pines (*Pinus ponderosa* Laws.) that had been infested about 2 weeks before treatment. Beetles infesting trees that had been treated with acid prior to the attack period were also unable to produce brood. Overall treating costs of $2 per tree were substantially lower than other direct-control methods.

Chatelain, M. P., and J. A. Schenk. 1983. Relative abundance, within tree distribution, emergence periods and feeding habits of insect associates of mountain pine beetle in lodgepole pine. Univ. Idaho For., Wildl. and Range Exp. Sta. Res. Note No. 39.

Chatelain, M. P. and J. A. Schenk. 1984. Evaluation of frontalin and exo-brevicomin as kairomones to control mountain pine beetle (Coleoptera: Scolytidae) in lodgepole pine. Env. Entomol. 13:1666-74.

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ABSTRACT

High-altitude color-infrared ERTS-1 underflight photos of a NASA test site in western Montana taken from a U-2 were evaluated for capability to resolve forest insect damage. Three insect outbreaks were known to occur within the test site: a bark beetle, mountain pine beetle *Dendroctonus ponderosae* Hopk.; and two defoliators - pine butterfly *Neophasia menapia* F. and F., and western spruce budworm *Choristoneura occidentalis* Free. Defoliation of ponderosa pine forests by pine butterfly was readily discernible

on color IR positive transparencies. Detection of mountain pine beetle damage was only partially successful. Defoliation of current year's foliage by western spruce budworm was not resolved.

Ciesla, W. M. 1978. The mountain pine beetle/lodgepole pine pest management system: Opportunities for putting new knowledge into practice. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 209-12.

ABSTRACT

Opportunities for putting new information on the management of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) forests into practice are explored. These are addressed from the viewpoint of what is currently known about insect/host interrelationships, alternative pest management strategies and how they can be integrated with resource management objectives, economics and environmental constraints. In addition, an accelerated program of knowledge utilization efforts, including informal workshops, demonstration of mathematical models and greater involvement of potential users of this technology, is recommended for the final year of this research and development program.

Clark, W. R. 1978. Theory and practice of mountain pine beetle management in lodgepole pine forests: A comment. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 208.

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Cobb, F. W., Jr., D. L. Wood, R. W. Stark and J. R. Parmeter, Jr. 1968. Theory on the relationships between oxidant injury and bark beetle infestation. Hilgardia 39:141-52.

Cole, D. M. 1973. Estimation of phloem thickness in lodgepole pine. USDA For. Serv., Res. Pap. INT-148, 10 pp.

ABSTRACT

Analysis of data from 288 trees shows that phloem thickness of lodgepole pines is strongly related to tree growth expressions that reflect past tree vigor, such as periodic basal area increment, and d.b.h. and tree height in conjunction with tree age. Broad habitat-type groupings also significantly influence phloem thickness. Equations presented for estimating phloem thickness of individual trees are usable in construction of phloem thickness distributions for lodgepole pine stands. Such distributions can aid in developing risk classifications for assessing vulnerability of lodgepole pine stands to mountain pine beetle attack.

Cole, D. M. 1978. Feasibility of silvicultural practices for reducing losses to the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc. For. Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 140-7.

ABSTRACT

A variety of standard silvicultural practices, and variations of them, have been proposed for reducing the losses caused by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) forests. This paper outlines silvicultural practices deemed applicable for a variety of lodgepole pine stand descriptions and management situations: it also discusses factors that limit application and some consequences of misapplication. The necessity that silvicultural practices be compatible with the requirements of forest growth regulation and with management for other resource values is stressed, and an example is given of the role of silvicultural practices in an integrated long-range program for reducing losses.

Cole, D. M. 1985. Effects of outbreaks in relation to host occurrence and resource concerns: occurrence of lodgepole pine stands according to habitat type and successional role. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 31-7.

Cole, D. M. 1985. Coordinating management objectives with silvicultural systems and practices: Acceptable silvicultural systems in relation to desired stand character and successional roles of lodgepole pine. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 45-6.

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Cole, W. E. 1962. The effects of intra-specific competition within mountain pine beetle broods under laboratory conditions. USDA For. Serv. Res. Note 97, 4 pp.

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Cole, W. E. 1970. The statistical and biological implications of sampling units for mountain pine beetle populations in lodgepole pine. Res. Popul. Ecol. 12:243-8.

Cole, W. E. 1973. Crowding effects among single-age larvae of the mountain pine beetle, *Dendroctonus ponderosa* (Coleoptera: Scolytidae). Env. Entomol. 2:285-93.

ABSTRACT

An experiment was conducted to determine the effect of crowding on: larval and adult survival; larval stadia duration; sex ratio of adults; reproductive capacity of adult female *Dendroctonus ponderosae* Hopkins.

To investigate distribution of the effect of crowding within a single age group, newly hatched larvae were used. The responses of these larvae and subsequent adults were observed after exposure to densities of 1, 3, 6, and 9 larvae (or adults) per unit of food supply for each of 3 time intervals.

Survival of 1st-stage larvae increased as crowding increased. Survival at the adult stage increased in Crowd 3, decreased in Crowd 9, and was not consistent in Crowd 6 as crowding duration lengthened. The rate of survival decreased as either crowding level increased or duration of crowding lengthened. Crowding influenced the rate of larval development, which in turn influenced sex ratio; i.e., as the 3rd and 4th larval stadia became shorter, more females and fewer males survived. Thus, the theoretical ratio of 1:1 shifted in favor of the female. The reproductive capacity of the female adult decreased as larval crowding increased. There was an apparent feeding stimulus through association that resulted in greater than 60% successful establishment of 1st-stage larvae when crowded.

Cole, W. E. 1973. Interaction between mountain pine beetle and dynamics of lodgepole pine stands. USDA For. Serv. Res. Note INT-170, 6 pp.

ABSTRACT

The influence of habitat types, diameter classes, and phloem thickness on beetle populations and the reverse, the influence of beetle populations on stand dynamics, form a coordinated interrelationship within the lodgepole pine ecosystem. The loss of trees to mountain pine beetles is partly a function of stand structure. Beetle population survival may be dependent upon either food supply or elevation, according to the particular habitat involved. This type of information can be used to estimate the probability of tree loss, risk of infestation, and brood survival.

Cole, W. E. 1974. Competing risks analysis in mountain pine beetle dynamics. Res. Popul. Eco. 15:183-92.

Cole, W. E. 1975. Interpreting some mortality factor interactions within mountain pine beetle broods. Env. Entomol. 4:97-102.

ABSTRACT

The mix of mortality factors within *Dendroctonus ponderosae* Hopkins populations was analyzed by using crude and general probabilities of death from specific causes and from all causes, within specified life stages and for the generation as a whole. These analyses provide the basis for discussion of actual results and some hypotehtical cases. Control efforts should accentuate one or more of the controllable causes of mortality or, perhaps eliminate one or more causes, if those remaining would be accentuated. The effect on total mortality of such action may depend heavily on the nature of the interactions among the causes. Knowledge of how mortality factors operate single and particularly in mix will permit additional characterization of the population dynamics of the mountain pine beetle.

Cole, W. E. 1978. Management strategies for preventing mountain pine beetle epidemics in lodgepole pine stands: Based on empirical models. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgpeole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 87-97.

ABSTRACT

Empirical models have been prepared describing the interaction between mountain pine beetle (*Dendroctonus ponderosae* Hopkins) and lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann). These models show the relationship between losses of lodgepole pine and survival of mountain pine beetle by life stages. Further, they identify stand characteristics conducive to mountain pine beetle epidemics and provide the basis for determining probabilities of infestation and resultant tree losses. This probability of infestation and tree loss can be determined for stands of varying diameter/phloem structure and can be further refined as additional information is gained. Harvesting techniques based on this probability can be applied strategically to prevent mountain pine beetle epidemics.

Cole, W. E. 1981. Some risks and causes of mortality in mountain pine beetle populations: a long-term analysis. Res. Popul. Ecol. 23:116-44.

Cole, W. E. and G. D. Amman. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. USDA For. Serv. Res. Note INT-95, 7 pp.

ABSTRACT

Tree losses resulting from infestation by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) were measured in two stands of lodgepole pine (*Pinus contorta* Dougl.) where the beetle population had previously been epidemic. Measurement data showed that larger diameter trees were infested and killed first. Tree losses ranged from 1 percent of trees 4 inches (d.b.h.) to 87 percent of those 16 inches and greater d.b.h. Numbers of adult beetle emergence holes averaged 1.3 per square foot of bark area in trees 7 inches d.b.h. and 62 in trees 18 inches and greater d.b.h. The observations indicate that large infestations of mountain pine beetle depend on the presence of large diameter trees within a stand of lodgepole pine, thus implying that beetle population growth is food-limited.

Cole, W. E. and G. D. Amman. 1980. Mountain pine beetle dynamics in lodgepole pine forests. Part I. Course of an infestation. USDA For. Serv. Gen. Tech. Rept. INT-89, 56 pp.

ABSTRACT

Much of this work is original research by the authors. However, published literature on the mountain pine beetle is reviewed with particular reference to epidemic infestations in lodgepole pine forests. The mountain pine beetle and lodgepole pine have evolved into an intensive and highly compatible relationship. Consequently, stand dynamics of lodgepole pine is a primary factor in the development of beetle epidemics. The diameter-growth relationship and the effects of environmental factors on the beetle population provide the basis for assessing potential tree losses and some forest management alternatives to be used. Stand susceptibility and acceptable risks are considered in the use of these management alternatives in order to achieve management's goals.

Cole, W. E., G. D. Amman, and C. E. Jensen. 1976. Mathematican models for the pine beetle - lodgepole pine interaction. Env. Entomol. 5:11-9.

ABSTRACT

Mathematical models describing losses of lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) and survival of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) by life stage were prepared from data covering a 13-yr period. The greatest survival and emergence of beetles/unit area of bark occurred in trees of large diameter. After most trees of large diam. were killed, gallery starts and egg production continued to increase. However, larval survival declined and emergence returned to the endemic level. At high densities of gallery starts and inches, beetle survival was low, probably because of excessive competition among larvae and drying of phloem. Under these conditions of stress, the sex ratio appears to shift further in favor of ♀ after most of the large trees are killed. These observations demonstrate the close association of beetle dynamics with diam. structure of lodgepole pine stands, and support the theory that epidemics are strongly dependent upon the presence of large trees having thick phloem.

Cole, W. E. and D. B. Cahill. 1976. Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine. J. For. 74:294-7.

ABSTRACT

Mountain pine beetle attacks in lodgepole pine stands are generally concentrated on trees of large diameter and thick phloem, and brood production is greatest within such trees. Three lodgepole stands infested at various epidemic levels were sampled in 1971 and pre-epidemic diameter and phloem thickness distributions were

estimated. Estimates of residual food supplies for beetles when partial cutting levels were applied to the data show that managing the stands so that trees did not reach 10 inches dbh would have substantially lowered the probabilities that epidemics would develop.

Cole, W. E., D. B. Cahill, and G. D. Lessard. 1983. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine: Preliminary evaluation, East Long Creek Demonstration Area, Shoshone National Forest, Wyoming. USDA For. Serv. Res. Note INT-333, 11 pp.

ABSTRACT

Diameter-limit and leave-tree cuts were tested as ways to reduce or minimize lodgepole pine losses to the mountain pine beetle. In the first year after treatment, loss reductions were proportional to the intensity of cut. According to the Rate of Loss Model, the 100-leave-tree cut was the best deterrent of recurring infestation, measured as amount of losses and length of time. The 100-leave-tree cut also should provide the best regeneration and has the added benefit of reducing dwarf mistletoe infection.

Cole, W. E., E. P. Guyman, and C. E. Jensen. 1981. Monoterpenes of lodgepole pine phloem as related to mountain pine beetles. USDA For. Serv. Res. Paper INT-281, 10 pp.

Cole, W. E. and M. D. McGregor. 1983. Estimating the rate and amount of tree loss from mountain pine beetle infestations. USDA For. Serv. Res. paper INT-318, 22 pp.

ABSTRACT

Because of recurrent depredations by the mountain pine beetle in lodgepole pine, managers have less than a 50-percent chance of growing lodgepole pine to 16-inch diameters in most stands. This paper describes a Rate of Loss Model that estimates the amount of tree and volume loss per year and the longevity of the infestation, and shows how the model can be incorporated into forest planning. The model assumes optimum conditions for the life of an epidemic. However, actual field conditions can cause beetle populations to

deviate from predictions causing a bit of overestimation, which is not considered serious in most infestation cases.

The model predictions, based on 2-inch diameter classes as populations, are further modified by habitat type. The classification provides the framework essential for organizing information to select alternative management activites for habitat types. The Rate of Loss Model has been integrated with the Insect and Disease Damage Survey (INDIDS) models to estimate mortality trends for stands with ongoing mortality or to obtain loss estimates by diameter class over infestation time for green stands, should they become infested.

One approach to modeling tree mortality caused by the mountain pine beetle uses FORPLAN to predict susceptible areas within analysis areas, which one would be affected, and the expected mortality over two decades. Or, when stands within analysis areas are identified through timber or stand exam surveys, beetle attack may then be simulated by a "prescription" that shows the effects of an epidemic in the absence of timber management.

The model has been verified using some 2,500 stands in the Forest Service's Northern Region. By using assessments from FORPLAN and harvesting in high hazard, susceptible stands before an epidemic develops, land managers should be able to minimize tree mortality caused by the beetle.

Cole, W. E. and R. F. Shepherd. 1967. The mountain pine beetle, *Dendroctonus ponderosae* Hopk., In A. G. Davidson and R. M. Prentice (Eds.). Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Can. Dept. For. Rural Dev. Publ. 1180, pp. 13-15.

Cole, W. E. and C. Weenig. 1967. A technique for inducing attacks and mating of the mountain pine beetle, *Dendroctonus ponderosae* (= *monticolae)* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60:857-8.

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Cook, J. A . 1959. Induced drought on lodgepole pine (*Pinus contorta* var. *latifolia* Engl.) and its relationship to successful mountain pine beetle (*Dendroctonus monticolae* Hopk.) attacks. For. Biol. Lab., Calgary, Alberta, 8 pp.

Conn, J. E., J. H. Borden, B. E. Scott, L. M. Friskie, H. D. Pierce, Jr., and A. C. Oehlschlager. 1983. Semio-chemicals for the mountain pine beetle, *Dendroctonus ponderosae*, in British Columbia: field trapping studies. Can. J. For. Res. 13:320-4.

ABSTRACT

The following compounds were field tested in multiple funnel or drainpipe traps as attractants for the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in British Columbia lodgepole pine, *Pinus contorta* var. *latifolia* Engelm. forests; *trans*-verbenol, 3-caren-10-ol, acetophenone, E-2-methyl-6-methylene-octa-2.7-dienol (myrcenol) and 2-p-menthen-7-ol (all female-produced volatiles which had proven attractive in laboratory bioassays): *exo*-brevicomin (produced by males); and a-pinene, B-pinene, 3-carene, B-phellandrene, terpinolene and myrcene (host tree monoterpenes), *trans*-verbenol was demonstrated to be a highly active aggregation pheromone, as was (±)-*exo*-brevicomin. Myrcene was the most effective synergistic monoterpene, while a-pinene was completely ineffective. In one experiment, 3-caren-10-ol caused a shift in favor of responding males, but the other female-produced volatiles were inactive.

* Cox, R. G. 1967. A potential project for control of mountain pine beetle in white pine. Progress Report No. 3. White Pine. Comm., Montana-Northern Idaho For. Pest Action Council, Lewiston, ID.

Cox, R. G. 1967. Studies of natural and synthesized attractants of the mountain pine beetle. Progress Report No. 4. White Pine Comm., Montana-Northern Idaho For. Pest Action Council, Lewiston, ID, 6 pp.

* Cox, R. G. 1968. Potentialities of reducing mountain pine beetle populations through the use of attractants. Paper presented at the northwest Scientific Association's Ann. Meeting, Ellensburg, WA. March 23.

Cox, R. G. 1969. Progress Report No. 6 on cooperative research on control of the mountain pine beetle. White Pine Committee, Montana-Northern Idaho For. Pest Action Council, Lewiston, ID, 14 pp.

Cox, R. G. 1972. Progress Report No. 8. Cooperative research on control of the mountain pine beetle in western white pine. Bark Beetle Committee, Montana-Northern Idaho For. Pest Action Council, Lewiston, ID, 28 pp.

ABSTRACT

This report reviewed and condenses results of seven years of cooperative "mission oriented" research to attempt to develop new methods of suppressing the mountain pine beetle *(Dendroctonus ponderosae)* in white pine *(Pinus monticolae)* in northern Idaho.

Forest tests in 1971 strongly demonstrated that the synthetic chemical messenger pondelure (a mixture of 9 parts *trans*-verbenol and 1 part *alpha*-pine) deployed on sticky traps significantly reduced mortality of white pine caused by the mountain pine beetle. A cost-benefit analysis showed the control effort to be justified. Thus pondelure becomes an important adjunct to the biological control of bark beetles in a way which is beneficial to the forest environment. Other 1971 tests assessed (1) additional pheromone candidate compounds, (2) alternate techniques and media for deploying the attractant, (3) the use of systemic chemicals injected into baited trees as a means of inhibiting beetle broods, and (4) the use of large-scale color aerial photographs to identify white pines killed by bark beetles.

Craighead, F. C. 1924. The Black Hills beetle practicing forestry on the Kaibab. For. Worker, Nov., 1924, p. 74.

Craighead, F. C. 1925. The *Dendroctonus* problems. J. For. 23:34-54.

Craighead, F. C. 1928. Interrelation of tree-killing bark beetles *(Dendroctonus)* and blue stains. J. For. 26:886-7.

Craighead, F. C. 1930. An annotated list of the important North American forest insects. USDA Misc. Pub. No. 74, 30 pp.

Craighead, F. C., J. M. Miller, J. C. Evenden and F. P. Keen. 1931. Control work against bark beetles in western forests and an appraisal of its results. J. For. 29:1001-18.

ABSTRACT

Has control work against bark beetles paid? Approximately one million dollars have been expended on a number of control projects. This article is a discussion of the economics of control work and is a candid appraisal of what the money has bought in the way of values saved and of experience gained for guiding future control efforts. With bark beetles still important factors, the recommendations for control policies here offered are particularly timely.

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Creasap, V. L. M. 1976. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, State and private land, South Pass City and Atlantic City, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-10, 4 pp.

Creasap, V. L. M. 1976. Biological Evaluation. Mountain pine beetle. Ute Pass DCA, Pike National Forest and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-13, 4 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, State and private land, South Pass City and Atlantic City, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-2, 2 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Middle Park, Colorado, Arapaho National Forest, BLM, State and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-3, 2 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. National Forest lands, Colorado Front Range, Arapaho, Roosevelt, Pike and San Isabel National Forests. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-4, 3 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Bighorn National Forest and adjacent BLM, State and private lands, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-6, 3 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Salida and San Carlos Ranger Districts, Pike and San Isabel National Forests, Colorado. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-7, 3 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Colorado Front Range Vegetative Management Pilot Project Area. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-9, 4 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, BLM, State and private lands, South Pass City and Atlantic City, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-10, 6 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. East Long Creek Timber Sale, Wind River Ranger District, Shoshone National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-11, 3 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming, Black Hills National Forest and adjacent State and private lands of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-12, 6 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Colorado Front Range, Arapaho and Roosevelt, Pike and San Isabel National Forests and adjacent lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-13, 6 pp.

Creasap, V. L. M. 1978. Biological Evaluation. Mountain pine beetle. Bighorn National Forest and adjacent BLM, State and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept No. R2-78-1, 4 pp.

Creasap, V. L. M. 1978. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, State and private land, South Pass City and Atlantic City, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-2, 2 pp.

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Creasap, V. L. M. and C. D. Minnemeyer. 1976. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-8, 8 pp.

Creasap, V. L. M. and C. D. Minnemeyer. 1976. Biological Evaluation. Mountain pine beetle. Colorado Front Range, Arapaho and Roosevelt, Pike and San Isabel National Forests and adjacent lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-9, 11 pp.

Crookston, N. L. 1979. Predicting the outcome of management activities in mountain pine beetle susceptible lodgepole pine stands. In C. L. Morris (ed.). Integrated pest management for forest insects: where do we stand today? Soc. Am. For., Wash. D.C. pp. 276-80.

Crookston, N. L., R. C. Roelke, D. G. Burnell, and A. R. Stage. 1978. Evaluation of management alternatives for lodgepole pine stands using a stand projection model. In: Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 114-22.

ABSTRACT

Silvicultural planning requires reliable estimates of stand growth, species and tree size composition, and mortality levels. Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations are inherent events in the development of many lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands. Therefore, tree mortality expected from future infestations must be considered when planning for the use of stands which may sustain appreciable beetle-caused mortality. The mountain pine beetle population dynamics simulation program (MPBMOD) has been coupled to prognosis model for stand development (TREMOD). Together these models form a unified program (TREINS1) which can be used by forest managers and research workers to explore management alternatives designed to reduce beetle-caused losses of lodgepole pine. This paper describes how the information produced by TREINS1 can be used by timber managers. The program design, limitations, data requirements and operation are discussed.

Crookston, N. L., R. W. Stark, and D. L. Adams. 1977. Outbreaks of mountain pine beetle in lodgepole pine forests--1945 to 1975. Univ. of Idaho, For., Wild. and Range Exp. Sta. Bull. No. 22, 7 pp.

ABSTRACT

The locations of mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), infestations in lodgepole pine (*Pinus contorta* Dougl.) forests between 1945 and 1975 are mapped. The intervals between infestations at selected locations from 1910 to 1975 were tabulated and found to vary between 6 and 64 years.

Dahlsten, D. L. and F. M. Stephen. 1974. Natural enemies and insect associates of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), in sugar pine. Can. Entomol. 106:1211-7.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae*, and 68 associated insect species were reared from infested sugar pine, *Pinus lambertiana*. Portions of three infested trees were sectioned

by height and the insects emerging from each were identified and recorded. In one tree the number of woodpecker strikes also was noted. The tops of two of the three trees were infested by another bark beetle, *Pityophthorus confertus*, and from these same two trees the most common parasite obtained was *Macromesus americanus*.

* DeLeon, D. 1929. Introductory study of the parasites, predators and some other associated insects of the mountain pine beetle in lodgepole pine. USDA Bur. Entomol, Coeur d'Alene, ID.

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* DeLeon, D. 1931. The important parasites, predators and associated insects of the mountain pine beetle in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

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DeLeon, D. 1935. The biology of *Coeloides dendroctoni* Cushman (Hymenoptera: Braconidae) an important parasite of the mountain pine beetle *Dendroctonus monticolae* Hopk.) Ann. Entomol. Soc. Am. 28:411-23.

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* DeLeon, D. 1935. Forest insects of California National Parks. Part I. Insects affecting sugar and ponderosa pine. Nat. Park Serv., Field Div. of For.

* DeLeon, D. 1939. List of fauna associated with the Black Hills beetle in ponderosa, lodgepole and limber pine. USDA For. Serv., Rocky Mtn. Sta., Fort Collins, CO.

* DeLeon, D. 1939. The biology and control of the Black Hills Beetle *(Dendroctonus ponderosae* Hopk.). Summary of studies in Colorado and Wyoming 1935-1938. USDA Bur. Entomol. and Plant Quar., 56 pp.

* DeLeon, D. 1940. Summary of 1939 Black Hills Beetle studies, Colorado and Southern Wyoming. USDA For. Serv., Rocky Mtn. Sta., Fort Collins, CO

DeLeon, D., W. D. Bedard and T. T. Terrel. 1934. Recent discoveries concerning the biology of the mountain pine beetle and their effect on control in western white pine stands. J. For. 32:430-6.

ABSTRACT

This paper is a summary of the studies during 1930, 1931, and 1932 in the white pine stands of eastern Washington and northern Idaho, of the biology and habits of *Dendroctonus monticolae* Hopk. Previous studies have never fully accounted for the rapid increase in the number of infested trees during outbreaks, nor have they adequately explained increases which have occurred subsequent to control work in several instances. Factual knowledge along such

lines is essential to the efficient planning and execution of future control projects.

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ABSTRACT

It is a well recognized fact that insects exert a powerful influence on the development and structure of a forest. Although many beneficial effects accrue from their activites, the changes which they bring about are frequently at odds with the desires of man. Losses of mature trees caused by insects are usually keenly realized because they deplete resources of present economic value; but less direct losses, which may occur concurrently in stands of low present value, frequently pass unnoticed.

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ABSTRACT

This paper gives a brief history of the destruction of standing timber resulting from an epidemic of the mountain pine beetle (*Dendroctonus monticolae* Hopk.) in the lodgepole pine stands of the Beaverhead National Forest, Mont. During the past decade the outbreak has swept through this area of 1,341,860

acres, killing approximately 57,756,000 trees above 3 inches in diameter. The total loss of merchantable trees 9 inches d.b.h. and above is estimated to be 77.3 percent.

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ABSTRACT

A simple generic model for the dispersion of pheromones in a forested ecosystem is presented. Methods for the calculation of various concentration related parameters are described. The influence of different micrometeorological conditions on concentration profiles is discussed. Two separate studies from two different geographical locations lend support to the predictions of the dispersion model. For two different species of *Dendroctonus* beetles, aggregation behavior was correlated with meteorological condition resulting from inversion profiles.

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* Furniss, R. L. 1941. Memorandom on examination of the 1940-41 pine beetle control project on the Wasatch National Forest -- June and July 1941. USDA Bur. Entomol., Portland, OR

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Gara, R. I., D. R. Geiszler, and W. R. Littke. 1984. Primary attraction of the mountain pine beetle to lodgepole pine in Oregon. Ann. Entomol. Soc. Am. 77:333-4.

ABSTRACT

Dispersing *Dendroctonus ponderosae* landed preferentially on lodgepole pines with fire scars and decay ($P = 0.023$ and $P = 0.008$, respectively, by joint binomial distribution analysis).

* Geiszler, D. R. 1979. Mountain pine beetle attack dynamics on lodgepole pine. M. S. thesis, Univ. of Washington, Seattle, 92 pp.

Geiszler, D. R. and R. I. Gara. 1978. Mountain pine beetle attack dynamics in lodgepole pine. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 182-7.

ABSTRACT

The "switching mechanism" by which mountain pine beetles (*Dendroctonus ponderosae* Hopkins) will kill lodgepole pine (*Pinus contorta* Douglas var. *murrayana* (Greville and Balfour) Engelmann) in groups during outbreaks was investigated. The agents causing beetles to switch from attacking a "focus" tree to attacking a "recipient" tree appear to be the sequential effects of aggregative and anti-aggregative pheromones. Analysis of the attack rates shows that recipient trees are initially attacked more quickly than trees baited with *trans*-verbenol and *a*-pinene. Regression analysis shows that beetles select recipient trees on the basis of tree diameter and distance from the focus tree. Thinning prescriptions based on a tolerance interval about a regression line relating diameters of recipient trees to distance from the focus tree might be used to reduce beetle kill.

Geiszler, D. R., V. F. Gallucci, and R. E. Gara. 1980. Modeling the dynamics of mountain pine beetle aggregation in a lodgepole pine stand. Oecologia 46:244-53.

ABSTRACT

At least once a year the mountain pine beetle searches for lodgepole pines that provide a suitable habitat for a new brood. After attacking females feed, they produce an attractant pheromone that causes beetles to aggregate and, during outbreaks, to usually mass attack the "focus" tree. Near the completion of mass attack, incoming beetles are repelled and initiate attacks on adjacent "recipient" trees. An understanding of this "switching" process is useful for prescribing measures that minimize beetle damage.

A mathematical model was developed to (1) describe beetle aggregation, (2) predict the relation of tree susceptibility and switching to changes in beetle density, (3) provide a structure for current knowledge, and (4) pose questions for further research. The model indicates that a high population density ensures mass aggregation and consequently successful tree colonization and switching. The model also indicates that the number of beetles attracted per attacking beetle differs from tree to tree, possibly depending on resin quality and production and/or the local flying density of beetles. Field and model results indicate that tree size appears to affect the repellence of beetles, suggesting that the attack density or the visual attractiveness of large trees is a factor. Further research could be directed at our assumptions on host resistance, repellence, pheromone emission rates, threshold concentrations, navigation, and pheromone dispersion.

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ABSTRACT

Describes a 4-legged cage 12 inches in diameter and 24 inches high, made from 20-mesh wire screen and a tractor funnel. A mason jar fits over funnel outlet to collect the emerging beetles.

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Gibson, K. E. 1977. Results of a pilot study to test the efficacy of three insecticides in preventing attacks by the mountain pine beetle in lodgepole pine. USDA For. Serv., Ogden, UT, 8 pp.

ABSTRACT

A pilot study was undertaken to test the efficacy of three Insecticides: Lindane, Sevin and Dursban in preventing attacks by the mountain pine beetle in lodgepole pine. Methods used in the selection, plot design and chemical application are described. Results indicating success or failure of the insecticides used are included.

Gibson, K. E. 1978. Results of a 1977 pilot project to evaluate the effectiveness of Sevin insecticide in preventing attacks by the mountain pine beetle in lodgepole pine on the Targhee National Forest, Idaho. USDA For. Serv., Intermountain Reg., Rept No. R-4 78-4, 22 pp.

Gibson, K. E. 1978. Damage assessment of a mountain pine beetle infestation, Targhee National Forest, Idaho. USDA For. Serv., Intermountain Reg. Rept. No. R-4 78-7, 5 pp.

ABSTRACT

Trend studies conducted on the Targhee National Forest, Idaho, indicate that in one stand, during the past five years, 86 trees per acre have been killed by the mountain pine beetle. This represents 69.5 percent of the stand 6 inches dbh and larger. These data could affect management decisions for similar stands of lodgepole pine.

Gibson, K. E. 1981. Permanent mountain pine beetle population trend plots: an update, 1981. USDA For. Serv., Northern Reg., Rept. 81-14, 4 pp.

Gibson, K. E. 1982. Permanent mountain pine beetle population trend plots: an update, 1982. USDA For. Serv., Northern Reg., Rept. 82-19, 5 pp.

Gibson, K. E. 1982. Management alternatives for lodgepole pine recreational facilities threatened by the mountain pine beetle. USDA For. Serv., Northern Reg., Rept. No. 82-27, 3 pp.

Gibson, K. E. 1983. Permanent mountain pine beetle population trend plots: an update, 1983. USDA For. Serv., Northern Reg., Rept. 83-17, 6 pp.

ABSTRACT

For the fourth year since their establishment, the six permanent plot locations in Montana were revisited following beetle flight in 1982. Beetle populations remained low in five of the six areas. Only in the Murr Creek plots did newly attacked trees represent an epidemic beetle population. In the Centennial Valley location, several plots had been logged. Growth and phloem thickness data were collected from Murr Creek, Boulder Creek, and Dunsire Creek in an effort to explain why beetle numbers are not building in these areas as rapidly as we had anticipated. Insufficient data has been collected, as yet, to reach meaningful conclusions.

Gibson, K. E., and D. Bennett. 1979. Overwintering survival of mountain pine beetle larvae and resultant effects on beetle populations in the Northern Region in 1979. USDA For. Serv., Northern Reg. Rept. No. 79-15, 10 pp.

ABSTRACT

During December 1978 and January 1979, temperatures reached all-time lows in some parts of Montana. Overwintering mountain pine beetle populations were sampled at 11 sites during February and March 1979. Effects of the extreme cold varied from site to site, with larval mortality ranging from 6 percent to 100 percent. As a result, beetle populations will likely be reduced substantially in some areas and affected little in others.

Gibson, K. E., M. D. McGregor, and D. D. Bennett. 1980. Establishment Report: Permanent mountain pine beetle trend plots, Montana, 1979. USDA For. Serv., Northern Reg., Rept. 80-8, 17 pp.

Gibson, K. E., M. D. McGregor and J. E. Dewey. 1980. Evaluation of a mountain pine beetle infestation in second growth ponderosa pine on the Crow Indian Reservation, Montana, 1979. USDA For. Serv., Northern Reg., Rept. No. 80-2, 11 pp.

ABSTRACT

The mountain pine beetle infestation in Corral, Little Corral, and Cache Creeks on the Crow Indian Reservation, Montana has been increasing for the past several years. Trees killed per acre averaged 38.8 in 1979. Our predictions for the future trend of the infestation, plus management alternatives to lessen its severity, are outlined in this report.

Gibson, K. E., M. D. McGregor and R. D. Oakes. 1985. Mountain pine beetle infestation in ponderosa pine on Crow/Northern Cheyenne Indian Reservations, Montana, 1984. USDA For. Serv., Northern Reg., Rept. No. 85-9, 16 pp.

ABSTRACT

The mountain pine beetle infestation existing on the Crow Indian Reservation (IR) since the early 1970's, and later developing principally in the western portion of the Northern Cheyenne IR, continued into 1984. Survey results indicate the infestation is still building on both Reservations. To help develop beetle management strategies appropriate

for stands in eastern Montana, studies to demonstrate the effects of several partial-cut regimes have been initiated. That project and currently held management philosophies for mountain pine beetle in second-growth ponderosa pine are discussed.

* Graves, H. S. 1897-98. 19th Ann. Rept. U. S. Geol. Survey, Pt. 5, p. 87.

Gray, B., R. F. Billings, R. I. Gara and P. L. Johnsey. 1972. On the emergence and initial flight behaviour of the mountain pine beetle, *Dendroctonus ponderosae*, in Eastern Washington. Z. angew Entomol. 71:250-9.

ABSTRACT

Emergence from ponderosa pine and initial flight behaviour of the bark beetle, *Dendroctonus ponderosae* were studied under field conditions. Hourly emergence increased as ambient temperatures rose from 20 to 30°C but declined markedly about 30°C. Essentially no emergence activity occurred on days when temperatures remained below 16°C. Under optimal temperature conditions (23-30°C), peak hourly emergence did not synchronize with maximum daily temperatures, suggesting that emergence is controlled rhythmically. The average sex ratio of emergent adults was 1 male to 1.4 females, although diurnal variation was considerable. In flight tests, newly emergent adults generally flew with the wind in the absence of pheromones. In contrast, in the presence of synthetic *trans*-verbenol and fresh host material, most male and female beetles flew directly towards the attraction source against the wind. Flight exercise was not a prerequisite to olfactory response. Flight height above the ground appeared to be independent of either ambient temperature or wind speed. Although the proportion of beetles which responded to attractants decreased with increasing wind speeds, several beetles flew against winds exceeding 7.5 km/h.

Griffin, D. N. 1975. Thinning a ponderosa pine stand to reduce mountain pine beetle caused mortality on the Ninemile District, Lolo National Forest. M.S. Thesis, Wash. St. Univ., Pullman, 46 pp.

ABSTRACT

A mountain pine beetle outbreak near Missoula, Montana killed an estimated 100,000 ponderosa pine trees from 1969 to 1971. A sanitation low thinning was installed in 1971 to find out if thinning even-aged, second-growth, mixed ponderosa pine and Douglas-fir stands would reduce beetle killed trees. The results of the five year study are discussed for a control unit and a thinned unit. In general, groups of trees are killed and tree mortality varies directly with basal area per acre. The variable plot data show that the diameter and height of the dead trees are almost identical with the average diameter and height of all pine trees in each basal area category. However, more small diameter trees are killed than larger diameter trees when the plot data are averaged for the entire stand. Thinning the Issac Creek stand appears to have drastically reduced beetle kill but thinning might have reduced the stand's volume growth more than the beetle has reduced stand growth. This paper briefly reviews the literature on thinning ponderosa pine stands to prevent mountain pine beetle attack and the effect thinning has on the growth of ponderosa pine stands.

* Hall, R. C. 1953. An improved appraisal survey method for bark beetle damage in ponderosa and Jeffrey pine in the California Reg. Calif. For. and Range Exp. Sta., Berkeley, CA

* Hall, R. C. 1964. Results of thinning ponderosa pine in reducing insect-caused losses, Joseph Creek Basin, Modoc National Forest. USDA For. Serv., Div. Timber Mgmt, San Francisco, CA, 12 pp.

* Hall, R. C. and G. R. Davies. 1968. Mountain pine beetle epidemic at Joseph Creek Basin, Modoc National Forest. USDA For. Serv., Div. Timber Mgmt., San Francisco, CA, 22 pp.

Hall, R. C. and J. R. Pierce. 1965. Sanitation treatment for insect control. USDA For. Serv., Div. Timber Mgmt. Report, R-5, 21 pp.

* Hamel, D. R. 1977. Status of mountain pine beetle infestations in second-growth ponderosa pine stands, Little Rocky Mountains, Fort Belknap Reservation, Montana, 1977. USDA For. Serv., Northern Reg., Rept No. 77-18, 6 pp.

Hamel, D. R. 1978. Results of harvesting strategies for management of mountain pine beetle infestations in lodgepole pine on the Gallatin National Forest, Montana. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 192-6.

ABSTRACT

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemics in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are correlated with large diameter, thick-phloemed trees, and decline of epidemics is associated with loss of these trees. Beetle brood production is directly correlated with phloem thickness, which is directly related to tree diameter. Probabilities of mountain pine beetle-caused losses to lodgepole pine can be developed from phloem thickness/tree diameter distribution data. Based on these probabilities, harvesting strategies were implemented in 1974 on the Gallatin National Forest to reduce average tree diameter and assess the effect on population build-up. Harvesting of four 16-ha (40-acre) blocks within heavily infested areas, based on diameter and phloem distributions, was completed in 1976. A 3-year post-harvest evaluation will determine the efficacy of this management alternative. Preliminary results indicate beetle population reductions in blocks harvested to 25- and 30-cm (10- and 12-inch) diameter limits, but population build-up in the block harvested to an 18-cm (7-inch) limit and in the block harvested on the basis of phloem thickness. Population build-ups were also noted in check blocks.

Hamel, D. R., G. D. Amman, M. D. McGregor, W. E. Cole, and L. A. Rasmussen. 1975. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana. USDA For. Serv., Northern Reg., Establishment Rept. No. 75-12, 11 pp.

* Hamel, D. R. and M. D. McGregor. 1976. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana. USDA For. Serv., Northern Reg., Rept. No. 76-3, 7 pp.

* Hamel, D. R. and M. D. McGregor. 1976. Evaluation of mountain pine beetle infestations; Lap, Cool, Lang, and Caribou drainages, Yaak Ranger District, Kootenai National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 76-6, 10 pp.

Hamel, D. R. and M. D. McGregor. 1976. Biological notes on the emergence of mountain pine beetle and associates from lodgepole pine, Gallatin National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. No. 76-7, 7 pp.

ABSTRACT

Emerged beetles were first collected July 17 and peak emergence occurred between August 10 and 26, 1975. Density of attacks averaged four per 0.5 ft.^{2} (0.05m^2). Parent to brood ratio was 1:4.6. Thirteen associate insects, representing six families of Coleoptera and one of Diptera, were recovered. Associates included predators and secondary bark beetles. Future studies dependent on mountain pine beetle emergence require initiation or completion prior to mid-July.

* Hamel, D. R., M. D. McGregor, and M. J. Berg. 1975. Status of mountain pine beetle infestations, Yellowstone National Park, Wyoming, 1973. USDA For. Serv., Northern Reg., Rept. No. 75-4, 7 pp.

* Hamel, D. R., M. D. McGregor, and M. J. Berg. 1975. Status of mountain pine beetle infestations, Yellowstone National Park, Wyoming, 1974. USDA For. Serv., Northern Region, Rept. No. 75-6, 6 pp.

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* Hamel, D. R., M. D. McGregor, and R. D. Oakes. 1977. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Gallatin National Forest, Montana. Progress Report - 1976. USDA For. Serv., Northern Reg., Rept. No. 77-6, 7 pp.

* Hamel, D. R., M. D. McGregor, and R. D. Oakes. 1977. Evaluation of a mountain pine beetle infestation, Jack Creek Drainage, Madison District, Beaverhead National Forest, Montana, 1976. USDA For. Serv., Northern Reg., Rept. No. 77-9, 8 pp.

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* Hamel, D. R. and R. D. Oakes. 1977. Evaluation of a mountain pine beetle infestation, Gold Creek Drainage, Rexford District, Kootenai National Forest, Montana. 1976. USDA For. Serv., Northern Reg., Rept. No. 77-10, 8 pp.

* Hamel, D. R. and R. D. Oakes. 1977. Status of mountain pine beetle infestations in second-growth ponderosa pine stands, Little Belt and Big Snowy Mountains, Lewis and Clark National Forest, Montana. 1976. USDA For. Serv., Northern Reg., Rept. No. 77-14, 6 pp.

* Hamel, D. R., R. D. Oakes, and R. Hothem. 1977. Potential for infestation by mountain pine beetle in lodgepole pine stands, Hungry Horse District, Flathead National Forest, 1977. USDA For. Serv., Northern Reg., Rept. No. 77-11, 6 pp.

Haneman, Deirdre M. 1983. Mountain pine beetle, Shirley Mountains, Wyoming-1982. USDA For. Serv., Rocky Mtn. Reg., Bio Eval. R2-83-3, 12 pp.

Haraden, R. C. 1982. United States National Park Service management policies and their relationship to mountain pine beetle pest management programs. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/ USDA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 54-57.

Harris, J. W. E., A. F. Dawson, and R. G. Brown. 1982. Evaluation of mountain pine beetle damage using aerial photography, Flathead River, B. C., 1980. Env. Can., Can. For. Serv., Pacif. For. Res. Cent., BC-X-228, 10 pp.

ABSTRACT

A low-budget multistage sampling procedure was applied in 1980 to a 14,750-ha area in the Flathead River Valley in southeastern British Columbia. Lodgepole pine (*Pinus contorta*) stands with trees killed by mountain pine beetle, *Dendroctonus ponderosae*, were sketch-mapped during aerial surveys. Twenty-six 1-ha airphoto plots at a scale of 1:5,000 were established on a grid pattern, using Kodak MS Aerochrome 2448 true color transparency film, together with a subsample of nine 0.25-ha ground subplots.

Ground-to-airphoto dead-tree count ratios were calculated for the nine subplots and beetle-killed pine were counted on the 26 photo plots. The "ground-corrected average number of dead trees per hectare" was determined for the 26 photo plots by multiplying the average number of trees killed per hectare on the 26 photo plots by the average of the nine subplot ratios. The number of killed trees was then estimated for the total area. A height-diameter curve was constructed from ground subplot data to calculate an average tree volume, which was applied to the total estimated number of killed trees to estimate the total volume loss for the area.

In the affected area, an estimated 5.3 million trees had been killed since 1976, mostly from 1979 attack. Volume losses were over 1.3 million cubic meters.

Sampling error was 18.5% for tree counts and 38.9% for volume. Ninety-three per cent of the volume loss occurred in trees were dbh of 15 cm or larger. Study costs were about 85 cents per hectare. An improved sampling design based on this experience is described. It would use 1:6,000 70-mm color photography with sketch-mapping. 4-ha airphoto plots and 0.25-ha photo-ground subplots.

Harvey, R. D., Jr. 1979. Rate of increase of blue stained volume in mountain pine beetle killed lodgepole pine in northeastern Oregon, USA. Can. J. For. Res. 9:323-6.

ABSTRACT

Recently killed lodgepole pine *(Pinus contorta* Dougl.) were examined to determine rate of spread of blue stain fungi introduced by mountain pine beetle *(Dendroctonus ponderosae* Hopk.). Trees were felled, dissected at 2.5 m intervals, and photographed at each cross section to determine area of stain. Rate of spread is so rapid that salvaging mountain pine beetle killed lodgepole pine prior to severe staining is difficult.

Hawksworth, F. G., C. K. Lister, and D. B. Cahill. 1983. Phloem thickness in lodgepole pine: its relationship to dwarf mistletoe and mountain pine beetle (Coleoptera: Scolytidae). Env. Entomol. 12:1447-8.

ABSTRACT

A generally accepted hypothesis is that lodgepole pines infected by dwarf mistletoe *(Arceuthobium americanum)* are less susceptible to mountain pine beetle, *Dendroctonus ponderosae,* because they have thinner phloem than uninfected trees. This Colorado study based on 1,051 trees, indicates that there is little relationship between dwarf mistletoe intensity and phloem thickness. Therefore, we conclude that there is little correlation between dwarf mistletoe and mountain pine beetle activity, at least in Colorado.

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Heinricks, J. 1983. The lodgepole killer. J. For. 81:289-92.

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Hester, D. A. 1939. Instructions for surveys and control of bark beetle outbreaks in the Central Rocky Mountain Region. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO, 19 pp.

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ABSTRACT

The genetic relationship between two sibling bark beetle species from northern California, the Jeffrey pine beetle, *Dendroctonus jeffreyi* Hopkins, and the mountain pine beetle, *D. ponderosae* Hopkins, was examined by electrophoresis. The genetic differences found between the Jeffrey pine beetle and the mountain pine beetle support their current designation as separate species. Two gene loci were fixed for different alleles in the two groups and provide strong evidence that gene flow does not occur between them. At several other loci, less striking but nevertheless significant differences were observed. The level of overall genetic similarity between the Jeffrey pine beetle and the mountain pine beetle was much lower than that found between conspecific populations of either group.

Hinds, T. E., L. R. Fuller, E. D. Lessard, and D. W. Johnson. 1984. Mountain pine beetle infestation and Armillaria root disease of ponderosa pine in the Black Hills of South Dakota. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-30, 7 pp.

ABSTRACT

A total of 115 trees were examined on 40 plots located throughout the northern Black Hills National Forest. A significant association (P = 0.05) was found between *Armillaria mellea* root disease and ponderosa pine tree mortality attributed to mountain pine beetle infestation. Seventy-five percent of the dead trees, 28% of the currently beetle-infested trees, but none of the live trees had *A. mellea* root infection. All trees had good crown

ratios and were equally distributed between single- and two-storied stands of moderate basal area on good quality sites.

* Hoffman, C. H. 1948. Mountain pine beetle control aerial dispersion of DDT. Agr. Res. Cnter., Beltsville, MD.

Homestake Mining Company. 1963. Black Hills beetle - Grim foe of Rocky Mountain pines. Share Bits 14(8):2-23.

* Hopkins, A. D. 1893. Damage to forests by the destructive pine beetles. Insect Life 5:187-9.

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Hopkins, A. D. 1902. Insect enemies of the pine in the Black Hills Forest Reserve. USDA Div. Entomol. Bull. 32, 24 pp.

Hopkins, A. D. 1905. The Black Hills beetle. USDA Bur. Entomol. Bull. 56, 24 p.

* Hopkins, A. D. 1906. Bark beetle depredations of some fifty years ago in the Pike's Peak region of Colorado. Proc. Entomol. Soc. Wash. 8:4-5.

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Hopkins, A. D. 1910. Insects which kill forest trees. Character and extent of their depredations and methods of control. USDA Bur. Entomol. Circ. No. 125.

Hopkins, A. D. 1910. Some insects injurious to forests. USDA Bur. Entomol., Bull. No. 58, 114 pp.

Hopkins, A. D. 1912. Insect damage to standing timber in the National Parks. USDA Bur. Entomol., Circ. No. 143, 10 pp.

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* Hopping, G. R. 1921. The control of bark-beetle outbreaks in British Columbia. Can. Dept. Agr., Entomol. Gr., Cir. 15.

* Hopping, G. R. 1950. Timber types in relation to insect outbreaks in the Canadian Rocky Mountains. 81st An. Rept. Entomol. Soc. Ont.:72-5.

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Hopping, G. R. and G. Beall. 1948. The relation of diameter of lodgepole pine to incidence of attack by the bark beetle, *Dendroctonus monticolae* Hopkins. For. Chron. 24:141-5.

Hopping, G. R. and W. G. Mathers. 1945. Observations on outbreaks and controls of the mountain pine beetle in the lodgepole pine stands of Western Canada. For. Chron. 21:98-108.

Hostetler, B. B. 1978. Biological Evaluation. Mountain pine beetle. Black Hills National Forest and adjacent Federal, State and private lands of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-3, 5 pp.

Hostetler, B. B. and R. W. Young. 1979. A pilot survey to measure annual mortality of ponderosa pine caused by the mountain pine beetle in the Black Hills of South Dakota and Wyoming. 1977. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-15, 20 pp.

Hostetler, Bruce B. and Robert W. Young. 1979. Estimation procedures for determining annual tree mortality caused by the mountain pine beetle. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-20, 25 pp.

ABSTRACT

Multistage sampling techniques were used in 1978 to estimate ponderosa pine mortality caused by the mountain pine beetle in the Black Hills of South Dakota and Wyoming. Using aerial sketch mapping information, the survey area of 651,000 acres (263,000 ha) was stratified into 3 intensity classes based on the estimated number of dead trees per acre. Each of the 2 highest intensity classes or strata were sampled from large scale (1:6,000) color aerial photographs and on the ground. Samples were selected using systematic random procedures in the first stage and probabilities proportional to size in the second stage.

Correlations between photo and ground counts were very good for each stratum sampled. On the 303,000 acres sampled, an estimated 318,000 ponderosa pine representing a volume of 5,629,000 cubic feet were killed in 1978. These number and volume estimates had standard errors of 4.2 and 7.2 percent, respectively.

Hughes, P. R. 1973. Effect of alpha-pinene exposure on *trans*-verbenol synthesis in *Dendroctonus ponderosae* Hopk. Die Naturwissenschaften 60:261-2.

Hughes, P. R. 1973. *Dendroctonus:* Production of pheromones and related compounds in response to host monoterpenes. Z. Ang. 73:294-312.

ABSTRACT

Bark beetles in the genus *Dendroctonus* produce a number of volatile compounds upon contact with host oleoresin during the initial periods of attack. These compounds, not found in the host and apparently oxidation products of the monoterpene fraction, were also produced when the beetles were exposed to individual monoterpene vapors or when terpenes were applied topically. A linear relationship was noted in female *D. brevicomis* between the period of exposure to alpha-pinene and the production of the terpene alcohol *trans*-verbenol. Removal of the antennae or maxillary and labial palpi which are major centers of chemoreception failed to alter this relationship. Detection of these various oxidation products in the hemolymph of *D. ponderosae* and *D. valens* after exposure to certain monoterpenes established that ingestion of terpenes is not necessary to their production and that the metabolism occurs outside of the alimentary canal. The character of these metabolic products suggested that a non-specific mechanism of oxidation of cyclic compounds at the allylic carbons is common in *Dendroctonus*. In addition, the production of a six carbon alcohol on exposure to alpha-pinene suggests that cleavage of the terpene molecule may occur in some cases. *Exo*-brevicomin in female *D. brevicomis* was found to decline significantly after mating.

These studies provided the basis for a working hypothesis on the origin and mechanism of synthesis of one class of scolytid aggregating pheromones. Furthermore, techniques are presented which may help in the future isolation and identification of these pheromones.

Hymun, B. G. and A. A. Berryman. 1980. *Dendroctonus ponderosae* (Coleoptera: Scolytidae): preaggregation landing and gallery initiation on lodgepole pine. Can. Entomol. 112:185-91.

ABSTRACT

Landing rates as monitored by landing traps indicate that the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is not attracted to lodgepole pine, *Pinus contorta* Dougl., prior to the first gallery start. Bark terpene odors and DBH were not correlated with beetle landing rates, with the exception of beta-phellandrene which accounted for a statistically significant 18% of the variation in landing rates. Beetles were unable to distinguish between hosts, dead hosts and nonhosts during landing. The elderberry pith bioassay indicated the presence of a gallery initiation stimulant in the bark.

Johnson, David W. 1982. Dwarf mistletoe and mountain pine beetle, Middle Mountain and Diamond Peak, Little Snake Resource Area, Bureau of Land Management, Colorado-1982. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-82-6, 6 pp.

Johnson, D. W., L. C. Yarger, D. C. Minnemeyer and V. E. Pace. 1976. Dwarf mistletoe as a predisposing factor for mountain pine beetle attack of ponderosa pine in the Colorado Front Range. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-4, 7 pp.

* Johnson, J. W. 1942. The composition of insect infestations in ponderosa and jeffrey pines, Lassen National Forest, seasons of 1940 and 1941. USDA Bur. Entomol, Berkeley, CA.

Johnson, P. C. 1940. Entomological considerations in utilization of insect-killed ponderosa pine. J. Econ. Entomol. 33:773-6.

Johnson, P. C. 1949. Determining bark beetle hazard of pine stands in northeastern California. J. For. 47:277-84.

ABSTRACT

The proportion of trees and volume in trees recently killed by bark beetles, and the proportion of live trees now classified as highly susceptible to beetle attack may be used as indices of beetle hazard in northeastern California pine lands. These same indices afford a basis for determining control measures and estimating their cost.

* Johnson, P. C. 1951. Height of broods as a factor affecting the treatment of standing lodgepole pine trees infested by the mountain pine beetle. USDA Bur. Entomol., Coeur d'Alene, ID.

Johnson, P. C. 1972. Bark beetle risk in mature ponderosa pine forests in western Montana. USDA For. Serv. Res. Paper. INT-119, 32 pp.

ABSTRACT

The Ponderosa Pine Risk Rating System developed in California was studied in western Montana to determine whether it could effectively identify individual mature trees most frequently killed by the western pine beetle, *Dendroctonus brevicomis* LeConte, or the mountain pine beetle, *D. ponderosae* Hopkins (Coleoptera: Scolytidae).

Risk 3 and Risk 4 trees--the high risk trees of the four-rating system--comprised 20 percent of the board-foot volume of 12,000 merchantable, risk rated ponderosa pine trees at 35 localities. On study plots in 22 of these localities, ponderosa pine stands that remained undisturbed throughout the study intially contained 17 percent of their total pine volume in Risk 3 and Risk 4 trees. Risk 3 and Risk 4 trees, however, made up 76 percent of the volume of all ponderosa pine trees killed by populations of the two pine beetles on these plots during the study.

Ponderosa pine mortality from the two pine beetle species was consistently low during the study, amounting to a mean of only 15.5 board feet per acre per year on the 22 undisturbed study plots--an amount considerably less than the estimated gross ponderosa pine increment on the same plots.

Subsidiary information obtained from the study indicated that (1) external crown characteristics used by the risk rating system in California to delineate the risk of mature ponderosa pine trees to attack by the western pine beetle were equally effective for this purpose in western Montana; (2) Risk 3 and Risk 4 ponderosa pine trees, together, grew an average of 0.18 inch radially during one 10-year period of the study, and Risk 1 and Risk 2 pine trees

grew an average of 0.43 and 0.31 inch, respectively; (3) in 15 mature ponderosa pine stands where soil characteristics were measured, Risk 3 and Risk 4 trees were progressively more abundant as the fertility, productivity, and water-holding capacity of the soils decline; and (4) the mountain pine beetle was not an important primary killer of mature ponderosa pine trees during the study, and it exerted little influence in predisposing low risk trees to attack by the western pine beetle.

It was concluded from the study that managers of mature ponderosa pine forests in western Montana can use the risk rating system to assess the susceptibility of these forests, or of individual ponderosa pine trees in them, to lethal attacks of the western pine beetle for 10 years or more during periods of endemic beetle populations.

* Johnson, P. C. and R. F. Schmitz. 1965. *Dendroctonus ponderosae* Hopk. (Coleoptera:Scolytidae), a pest of western white and ponderosa pines in the northern Rocky Mountains. USDA For. Serv., 4500-FS-INT-2202, 87 pp.

Jones, R. G. and W. G. Brindley. 1970. Tests of 8 rearing media for the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae) from lodgepole pine. Ann. Entomol. Soc. Am. 63:313-6.

ABSTRACT

Eight rearing media were tested for suitability for rearing the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, from lodgpeole pine, *Pinus contorta* Douglas. The 2 media containing cellulose rather than lodgepole phloem were not successful. Two phloem-based media produced adults from 36.7 and 21.4% of the 1st stage larvae applied to them. Development time of the insects, size and condition of the adults, and ability of the adults to produce viable eggs when artificially infested in lodgepole pine log sections were studied.

Wild adults mated on most media. Eggs were laid on 4 phloem-containing media but only 1 proved viable.

Katovich, Steven. A. 1984. A comparison of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, risk rating systems in an endemic situation. Univ. Wyo., M.S. Thesis, 115 pp.

Kaufmann, Merrill R. and Robert E. Stevens. 1984. Vigor of ponderosa pine trees surviving mountain pine beetle attack. USDA For. Serv. Res. Note RM-448, 5 pp.

* Keen, F. P. 1916. Report No. 4. Seasonal history of *Dendroctonus monticolae*. Project 15a. Ashland-Lamb's Mine Units. USDA For. Serv., San Francisco, CA.

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Keen, F. P. 1938. Insect enemies of western forests. USDA Misc. Pub. No. 273.

Keen, F. P. 1950. The influence of insects on ponderosa pine silviculture. J. For. 48:186-8.

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Keen, F. P. 1952. Bark beetles in forests. USDA Yearbook of Agric. 1952:688-94.

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Klein, W. H. 1973. Beetle-killed pine estimates. Photogramm. Eng. 39:385-8.

ABSTRACT

A study was undertaken to determine the feasibility of detecting mountain pine beetle-killed lodgepole pine with 35-mm color aerial photographs at a 1:5,000 scale. Photographs were obtained with a standard 35-mm camera from a light aircraft. Counts of dead trees were made from stereo photographs by untrained interpreters and compared to actual ground counts. Additionally, interpreters were asked to separate new faders from all other mortality. Both tree condition categories were discerned from the photos with acceptable accuracy, indicating the potential of 35-mm aerial photography as an inexpensive and effective measurement method. The method was to be applied operationally in 1971 within the framework of a double-sampling design.

Klein, W. H. 1973. Evaluating a mountain pine beetle infestation with the aid of 35 mm photography. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 8 pp.

Klein, W. H. 1974. Evaluating a mountain pine beetle infestation with the aid of 35 mm aerial photography - Report No. 2. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 5 pp.

Klein, W. H. 1975. Evaluating a mountain pine beetle infestation with the aid of 35 mm aerial photography - Report No. 3. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 6 pp.

Klein, W. H. 1976. Evaluating a mountain pine beetle infestation with 35 mm aerial color photogrpahy - Report No. 4. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 6 pp.

Klein, W. H. 1976. Preliminary report of a survey to measure the impact of the mountain pine beetle in a lodgepole pine forests. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 7 pp.

ABSTRACT

During the past two decades, the mountain pine beetle has seriously depleted the lodgepole pine forests of the Intermountain West. Using 35mm color aerial photography, a double sampling system, and permanently established plots, measurements of stand depletion were made in a 120,222 acre management area on the Targhee National Forest, Idaho, in 1972-73. Additional to measurements of standing live and beetle-killed timber, data was also obtained on reproduction, forage yield, habitat type, disease (mistletoe), and other factors that will yield insight into the effects of mountain pine beetle damage on other forest resources. A remeasurement of all plots in 1975 showed that although there was some additional tree mortality, there was a net increase in both lodgepole and total stand volume. Plans are to remeasure these plots at periodic intervals as a base (model) for predicting future yield.

Klein, W. H. 1978. Strategies and tactics for reducing losses in lodgepole pine to the mountain pine beetle by chemical and mechanical means. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For. Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 148-58.

ABSTRACT

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins), easily the most destructive bark beetle in the West, has ravaged the lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) forests of the northern Rockies since the turn of the century. The progress of mountain pine beetle epidemics in lodgepole pine is traced from a beginning in northern Montana in 1909 to full-scale outbreaks that progressed southward through the lodgepole pine forests of southern Idaho, western Wyoming and northern Utah. During the past two decades, the infestation pattern has reversed itself, with outbreaks recurring in parts of northern Utah, southern Idaho, western Wyoming, and back into Montana. Various control strategies employing a variety of methods, practically all of which entailed treatment of individual trees, were attempted, but at best only a few were touted as successful. The large-scale and costly control programs that were aimed at portions of large outbreaks and undertaken during the late 1950s and early 1960s in the Intermountain area failed to stop the infestations. During the 1970s, emphasis changed from individual tree control to individual tree protection. Methods are available for protecting high-value trees from beetle attacks, but they may be relatively costly and are impractical on a forest-wide basis. Individual tree treatment continues to be a management option, but a poor one. Long-lasting control can best be achieved by application of preventive techniques. In some instances, a do-nothing policy could be a viable alternative.

Klein, W. H. 1979. Measuring damage to lodgepole pine caused by the mountain pine beetle. In: USDA For. Serv. Gen. Tech. Rept. WO-8, pp. 35-42.

Klein, W. H. 1982. Estimating bark beetle-killed lodgepole pine with high altitude panoramic photography. Photo. Eng. & Remote Sensing 48:733-7.

ABSTRACT

Panoramic color IR aerial photography taken from a U-2C was evaluated to determine its effectiveness in quantifying annual mortality of lodgepole pine caused by mountain pine beetle. A multistage survey using probability proportional to size (PPS) at three levels was used to estimate numbers of trees and volume killed.

Mortality of lodgepole pine in 1977 was estimated at 1,891,510 ± 194,804 trees, and 27,001,000 ± 3,682,000 cubic feet of volume.

Problems encountered with interpretation and data analysis are discussed. The results suggest that panoramic photography can be effectively used to estimate annual mortality of lodgepole pine caused by mountain pine beetle over large areas.

Klein, W. H., D. D. Bennett and R. W. Young. 1979. A pilot survey to measure annual mortality of lodgepole pine caused by the mountain pine beetle. USDA For. Serv., Methods Application Group, Rept. No. 78-4, 15 pp.

ABSTRACT

A pilot survey utilizing multistage sampling techniques was undertaken on the Targhee National Forest during 1977 to measure annual mortality of lodgepole pine by the mountain pine beetle. The survey area, 397,000 acres, was stratified by aerial sketch-mapping into three intensity classes; each stratum was independently sampled by large scale (1:6000) color aerial photography and ground truth. Additional stand data was taken on randomly selected ground plots.

The correlations between photo and ground counts for each stratum were generally good. Stratification by aerial sketch-mapping reduced the population variance and improved the sampling errors. Mortality estimates of mountain pine beetle-killed lodgepole pine for 1976 were 3,609,627 trees and 64,761,000 cubic feet. Prior to 1976, the standing dead lodgepole pine was estimated at 17,751,000 trees and 249,515,000 cubic feet. The basal area ratio of the residual green stand to total dead was 63%.

Mountain pine beetle damage surveys will be conducted in portions of Montana, South Dakota, and Wyoming in 1978. Methods will be essentially similar to this survey with some modifications.

Klein, W. H., D. D. Bennett and R. W. Young. 1980. Evaluation of panoramic reconnaisance aerial photography for measuring annual mortality of lodgepole pine beetle. USDA For. Serv., Northern Reg., Rept. No. 80-2, 21 pp.

ABSTRACT

High elevation, panoramic infrared photography taken from a U-2 aircraft was evaluated to determine its effectiveness in quantifying annual mortality of lodgepole pine caused by the mountain pine beetle in a 520,640-acre outbreak in portions of the Beaverhead and Gallatin National Forests in Montana. A multistage, variable probability design using probability proportional to size (PPS) at three levels was used throughout the survey.

The results suggest that panoramic photography can be effectively used to provide precise estimates of mountain pine beetle-caused annual mortality of lodgepole pine over large areas. Mortality of lodgepole pine in 1977 was estimated at 1,891,510 ± 194,804 trees, and 27,001 M ± 3682 M cubic feet of volume. These estimates differed somewhat from a multistage aerial photo survey also conducted in 1978, the difference ascribed to different areas of coverage. Physical characteristics of this unconventional format are described, and suggestions for its future use in similar bark beetle damage surveys are recommended.

Klein, W. H., D. L. Parker, and C. E. Jensen. 1978. Attack, emergence, and stand depletion trends of the mountain pine beetle in a lodgepole pine stand during an outbreak. Env. Entomol. 7:723-7.

ABSTRACT

Yearly trends of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) mortality in relationship to attacking and emerged mountain pine beetle (*Dendroctonus ponderosae* Hopkins) populations were measured during the life span of an epidemic within a square-mile area.

Epidemic levels of infestation were recorded for 7 yr. with peak tree killing occurring the 4th yr. More small trees were killed than large ones, but in proportion to their occurrence the large trees were killed 1st and at a higher rate.

Both density and total numbers of attacking and emerged beetle populations exhibited marked changes during the course of the epidemic. The patterns of total attacking and emerging beetle populations were similar to the trend of annual tree mortality, but population densities expressed on a square-foot basis showed different trends. Generally, the density of attacking beetles increased during the epidemic, and while emergence remained relatively stable during the build-up years, it declined rapidly during and following the peak year of tree killing. Up to and including the year of maximum tree killing, trees of all sizes produced more beetles than they absorbed, but approached or fell below a hypothetical 1:1 emergence-attack ratio during the waning years of the outbreak. A greater percentage of emerged beetles became established in host trees during the build-up and peak year of the infestation than during the declining years.

Klein, W. H., L. E. Stipe, and L. V. Frandsen. 1972. How damaging is a mountain pine beetle infestation? A case study. USDA For. Serv., Br. For. Insect and Dis. Prev. and Cont., Ogden, UT, 7 pp.

* Klein, W. H. and A. C. Tegethoff. 1970. Forest insect and disease conditions in the Intermountain states during 1969. USDA For. Serv., Int. Mtn. Reg., 11 pp.

Knight, F. B. 1958. Methods of surveying infestation of the Black Hills beetle in ponderosa pine. For. Sci. 4:35-41.

Knight, F. B. 1959. Partial life tables for the Black Hills beetle. J. Econ. Entomol. 52:1199-1202.

ABSTRACT

Life tables have been developed for use in ecological studies of Black Hills beetle (*Dendroctonus ponderosae* Hopk.) populations. These tables reveal very high mortalities among the developing beetles for all classes of infestations. Decreasing infestations suffer more than 99% mortality; static infestations about 97% and increasing infestations more than 90%. The critical mortality period is between April and July of the spring following the initial attack on the trees, late in the life cycle of the insect.

Knight, F. B. 1959. Measuring trends of Black Hills beetle infestations. USDA For. Serv. Res. Note RM-37, 6 pp.

Knight, F. B. 1960. Sequential sampling of Black Hills beetle populations. USDA For. Serv. Res. Note 48, 8 pp.

Knight, F. B. 1967. Evaluation of forest insect infestations. Ann. Rev. Entomol. 12:207-28.

Knight, F. B. and F. M. Yasinski. 1956. Incidence of trees infested by the Black Hills Beetle. USDA For. Serv. Res. Note 21, 4 pp.

Kulhavy, D. L., A. D. Partridge and R. W. Stark. 1978. Mountain pine beetle and disease management in lodgepole pine stands: Inseparable. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 177-81.

ABSTRACT

Pest management strategies addressing only the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) may lead to recurrence of mountain pine beetle, occurrence of associated insects and expansion of disease problems. The roles of diseased lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) and of lodgepole pine with flooded root zones acting as triggers of mountain pine and associated bark beetle population build-ups are presented. Silvicultural treatments for dwarf mistletoe, and to a lesser extent for the rusts and root disturbances, are presented in the context of mountain pine beetle management. We conclude that the forest manager must consider the consequences of any silvicultural prescriptions on diseases and insects.

Kulhavy, D. L., A. D. Partridge, and R. W. Stark. 1984. Root diseases and blister rust associated with bark beetles (Coleoptera: Scolytidae) in western white pine in Idaho. Env. Entomol. 13:813-7.

ABSTRACT

Root systems of western white pine, *Pinus monticola* Douglas, were excavated with explosives and examined for pathogens. Data were also recorded on portions of the crown killed by blister rust caused by *Cronartium ribicola* Fisch. Statistical tests revealed a significant association between the bark beetles *Dendroctonus ponderosae* Hopkins and *Pityogenes fossifrons* (LeConte) and the root pathogen *Armillariella mellea* (Vahl. ex Fr.) Karst and between beetles and all root diseases. Ninety-two percent of the trees attacked by bark beetles had root diseases and 97% had either root diseases or blister rust. A discriminant analysis correctly classified 88% of the sample trees into two categories, trees infested with *D. ponderosae* or trees not infested with *D. ponderosae*, using the variable age (stump), diameter at 1.3 m in height, and percentage of the primary roots infected with pathogens. Major pathogenic organisms isolated from the roots included *A. mellea*, *Phaeolus schweinitzii* (Fr.) Pat., *Resinicium bicolor* (Fr.) Parm., *Verticicladiella* spp., and a *Europhium* strain. A hypothetical sequence of host tree invasion by blister rust, followed by infection by root diseases, and finally attacks by bark beetles, is postulated.

Landis, T. D. and R. H. Frye. 1974. Tree injury and mortality in the Dillon-Keystone area, Dillon Ranger District, White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-74-16, 7 p.

Lanier, G. N. and D. L. Wood. 1968. Controlled mating, karyology, morphology, and sex ratio in the *Dendroctonus ponderosae* complex. Ann. Entomol. Soc. Am. 61:517-26.

ABSTRACT

Laboratory mating experiments and observations on developmental rate, karyology, and morphology confirm the recent synonymy of *Dendroctonus monticolae* Hopkins with *D. ponderosae* Hopkins, but establish the species integrity of *D. jeffreyi* Hopkins, also previously considered a synonym of *D. ponderosae*. *D. monticolae* from British Columbia and 8 California localities were interfertile and morphologically similar. *D. ponderosae* from Colorado were interfertile with *monticolae* from California, but their mean pronotal widths, 2.44 mm and 2.10 mm, respectively, and indices of pronotal punctation, 5.43 and 6.12, respectively, were very significantly different. *D. monticolae* and its hybrid with *ponderosae* showed the karyotypic formula 11AA + Neo-XY.

D. jeffreyi is larger (pronotal width = 2.63 mm) and its pronotum less densely punctured (index - 4.19) than *monticolae* and *ponderosae*. The karyotype of *jeffreyi* is also 11A + Neo-XY, but the Neo-X is usually constricted and 1.4 times longer than the Neo-Y while the Neo-X of *monticolae* is rarely constricted and only slightly larger than the Neo-Y. In addition, a tiny supernumerary chromosome was present in some *jeffreyi*. In reciprocal pairings of *monticolae* and *jeffreyi*, none of the 846 eggs laid by 21 *monticolae* females hatched, but 8 larvae and 1 sterile female resulted from 362 eggs laid by 10 *jeffreyi* females. Five pairings of *jeffreyi* and *ponderosae* produced no brood.

Several *jeffreyi* (control) pairings showed a marked reduction in egg hatchability and only female progeny were produced. A male-lethal factor attacking the embryos is suggested, but pedigree data are insufficient to determine whether chromosomal or cytophasmic factors are involved.

Larsson, S., R. Oren, R. H. Waring, and J. W. Barrett. 1983. Attacks of mountain pine beetle as related to tree vigor of ponderosa pine. For. Sci. 29:395-402.

ABSTRACT

The relationship between tree vigor, measured as stem growth per unit of leaf area, and susceptibility to mountain pine beetle attacks was examined in a stocking-level experiment of ponderosa pine *(Pinus ponderosa* Laws.) in central Oregon. Vigor decreased as both tree density (basal area) and leaf area index increased. Low vigor trees were more often attacked by beetles than high vigor trees. Attacks increased below a vigor threshold of about 100 g of wood produced per square meter of leaf area per year, corresponding in this study to a basal area of 21 m^2ha^{-1} or a leaf area index of 2.9 m^2m^{-2}. For management of ponderosa pine, maintaining vigor through thinning will reduce the risk of mountain pine beetle attacks.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle Project #632 progress report, Black Hills National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-11, 9 p.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle, Bear Lodge Mountains, Black Hills National Forest - 1979. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-12, 7 pp.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle, South Dakota State Progress Report #1-1979. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-15, 8 pp.

Lessard, G. 1981. Biological Evaluation. Mountain pine beetle evaluation state, county and private lands, Casper Mountain, Wyoming - 1981. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-82-1, 12 pp.

Lessard, E. D. 1982. Interim Report. Mountain pine beetle evaluation, ponderosa pine stand risk rating using ground and aerial photographic surveys - 1981. USDA For. Serv., Rocky Mtn. Reg., 16 pp.

Lessard, Gene. 1982. Factors affecting ponderosa pine stand susceptibility to mountain pine beetle in the Black Hills-1981. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. No. R2-26, 16 pp.

Lessard, Gene. 1984. Biological Evaluation. Mountain pine beetle in the Black Hills of South Dakota and Wyoming-1984. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-84-7.

Lessard, Gene. 1984. High Country Integrated Pest Management Project post-suppression evaluation, Grand County, Colorado, 1984. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-84-9, 26 pp.

Lessard, G. and D. W. Johnson. 1981. Biological Evaluation. Mountain pine beetle, dwarf mistletoe, comandra rust in lodgepole pine, Roaring Fork and North Fork drainages, Little Snake River, Medicine Bow National Forest - 1981. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-4, 20 pp.

Lessard, G., D. W. Johnson, T. E. Hinds, and W. H. Hoskins. 1985. Association of Armillaria root disease with mountain pine beetle infestations on the Black Hills National Forest, South Dakota. USDA For. Serv., Methods Application Group, Rept. No. 85-4, 6 pp.

Lindgren, B. S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can. Entomol. 115:299-302.

ABSTRACT

The multiple funnel trap, an efficient, collapsible, non-sticky trap for scolytid beetles, consists of a series of vertically aligned funnels with a collecting jar at the bottom. The trap compared favorably with sticky traps and Scandinavian drainpipe traps for three species of ambrosia beetles and the mountain pine beetle. Minimum maintenance required for this trap allows for high efficiency in pheromone-based research, survey, and mass trapping of scolytid beetles.

Lindgren, S. 1983. Mountain pine beetle technical bulletin. Vancouver, B. C.:PMG/Stratford Projects Ltd., 4 pp.

Lister, C. K. 1971. Biological Evaluation. Mountain pine beetle. Routt National Forest, private land, Bureau of Land Management, Glenwood District, North Park, Colorado. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-2, 2 pp.

Lister, C. K. 1971. Biological Evaluation. Mountain pine beetle. Arapaho National Forest, Fraser and Sulphur Ranger Districts; Bureau of Land Management, Glenwood District; private land. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-4, 3 pp.

Lister, C. K. 1972. Biological Evaluation. Mountain pine beetle. Bighorn National Forest, Tongue Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-17, 2 pp.

Lister, C. K. 1972. Biological Evaluation . Mountain pine beetle. North Park, Colorado, Routt National Forest, Bureau of Land Management, and private land. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-20, 2 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Routt National Forest, Hahns Peak Ranger District, Harrison Creek. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-1, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Routt National Forest, Bears Ears Ranger District, Willow Creek. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-2, 2 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Medicine Bow National Forest, Encampment Ranger District, South Spring Creek, 1972. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-4, 4 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. North Park, Colorado, Routt National Forest, Bureau of Land Management, and private land. USDA For. Serv., Rocky Mtn. Reg. Rept. No. R2-73-6, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Roosevelt National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-7, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Medicine Bow National Forest, Encampment and Snake River Ranger Districts. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-8, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Arapaho National Forest and Bureau of Land Management, Granby-Middle Park. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-9, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Forest Service, National Park Service, Bureau of Land Management, State and private lands, Black Hills, South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-10, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-18, 3 pp.

Lister, C. K. 1978. Biological Evaluation. Mountain pine beetle. Evaluation of the proposed Beulah Cooperative Management Demonstration Area, Pike and San Isabel National Forests. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-5, 4 pp.

Lister, C. K. 1981. Biological Evaluation. Mountain pine beetle outbreak, Holy Cross Ranger District, White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-3, 15 pp.

Lister, C. K. 1982. Biological Evaluation. The mountain pine beetle outbreak potential of Eagles Nest Wilderness (East Side), 1982. USDA For. Serv., Rocky Mtn. Reg., R2-82-3, 7 pp.

Lister, C. K. and D. Leatherman. 1978. Biological Evaluation. Mountain pine beetle - Evaluation of the proposed Beulah Cooperative Management Demonstration Area. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-5, 4 pp.

Lister, C. K. and R. W. Young. 1981. 1979 Colorado Front Range mountain pine beetle survey. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-22, 19 pp.

ABSTRACT

A multistage survey to estimate tree mortality and volume on a statewide basis for Colorado was conducted in 1979. The survey methods are outlined in this report. The estimated number of faders (1978 attacked trees) was 327,443 trees from an infested area of 350,279 acres with an associated volume of 5.1 million cubic feet. Fader estimates and volumes pro-rated by ownership class are displayed for Colorado 1979 in the following table.

	Outbreak Area (M acres)	Number of trees (M trees)	Mortality (MMCF)
Colorado			
National Forest	177.5	163.5	2.6
Other Federal	7.0	6.9	0.1
State, County or Municipal	7.7	7.3	0.1
Nonindustrial Private	158.1	149.8	2.3
Total	350.3	327.5+15%	5.1

Utilizing the estimate of 1979 faders (327,443) and the new mountain pine beetle infestation ratio (0.28) the estimated number of 1980 faders (1979 attacks) tree loss, was estimated to be about 92,000 ponderosa pine trees.

Lyon, R. L. 1958. A useful secondary sex character in *Dendroctonus* bark beetles. Can. Entomol. 90:582-4.

Mahoney, R. L. 1978. Classifying lodgepole pine stands as resistant or susceptible to mountain pine beetle. Univ. Idaho, M.S. Thesis, 28 pp.

Mahoney, R. L. 1978. Lodgepole pine/mountain pine beetle risk classification methods and their application. In A. A. Berryman, G. D. Amman, R. W. Stark, and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 106-13.

ABSTRACT

Four mountain pine beetle (*Dendroctonus ponderosae* Hopkins)/lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stand risk classification methods are tested. Their application to management is discussed. The 24 lodgepole pine test stands were located in central Idaho and western Montana. A combination of the methods tested provides improved predictions of mountain pine beetle infestations, a better understanding of host/beetle interactions, and practical alternatives for lodgepole pine/mountain pine beetle management.

Manning, G. H. 1982. Impact of the mountain pine beetle on the economy of British Columbia. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 22-23.

* Massey, C. L. 1951. Heights of treatment of the Black Hills beetle in ponderosa pine and the relation of height of infestation to DBH, Roosevelt National Forest, 1950. USDA Bur. Entomol., Fort Collins, CO.

Massey, C. L., R. D. Chisholm and N. D. Wygant. 1953. Ethylene dibromide for control of Black Hills beetle. J. Econ. Entomol. 46:601-4.

Massey, C. L. and N. D. Wygant. 1949. An analysis of seasonal precipitation records as related to Black Hills beetle outbreaks. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO, 7 pp.

* Massey, C. L., N. D. Wygant, and R. I. Washburn. 1950. Tests with ethylene dibromide emulsions for control of the Black Hills beetle in ponderosa pine. USDA Bur. Entomol., Fort Collins, CO

Mata, S. A., Jr. 1972. Accuracy of determining mountain pine beetle attacks in ponderosa pine utilizing pitch tubes, frass, and entrance holes. USDA For. Serv. Res. Note RM-222, 2 pp.

ABSTRACT

Counts of external indicators of attacks by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, throughout the infested length of five sampled ponderosa pines, where 1.5 percent greater than actual attacks.

McBride, J. K. 1982. The need for action against mountain pine beetle on commercial timber and related lands. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv., Rept. BC-X-230, pp. 47-49.

McCambridge, W. F. 1962. Sexing Black Hills beetles, *Dendroctonus ponderosae* Hopkins. Ann. Entomol. Soc. Am. 55:723-4.

McCambridge, W. F. 1964. Emergence period of Black Hills beetles from ponderosa pine in the Central Rocky Mountains. USDA For. Serv. Res. Note RM-32, 4 pp.

McCambridge, W. F. 1967. Nature of induced attacks by the Black Hills beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60:920-8.

ABSTRACT

Attractants of *Dendroctonus ponderosae* Hopkins, made by attaching infested bolts to green trees or forcing attacks on such trees under screen cages, provided a means to study how the beetle attacks trees and stands. Attractant trees were always infested first; first attacks occurred below 8 ft., and generally below 4 ft. Initial attacks on adjacent trees, which occurred during the mass attack, appeared slightly higher on the trees but not higher than 10 ft. Subsequent attacks occurred below and above the initial attacks, with the mean height increasing with time. Trees

became infested at progressively greater distances from the attractant center. Infested trees were significantly larger than green trees within the radius of infestation. The greatest number of attacks was recorded at the end of the 4 pm to 6 am period.

McCambridge, W. F. 1968. Attraction of Black Hills beetle to ponderosa pine in the Central Rocky Mountains. N. Cent. Br. Entomol. Soc. Am. Proc. 23:137-40.

ABSTRACT

Infestations of Black Hills beetles can be established in preselected locations by the attraction produced from forced attacks to a small number of beetles. This procedure has made possible detailed observations on how trees and stands become attacked. Practical applications and limitations are discussed.

McCambridge, W. F. 1969. Spermatozoa in unemerged female mountain pine beetles, *Dendroctonus ponderosae* Hopk. Entomol. Soc. Ontario Proc. 100:168-70.

ABSTRACT

Less than 2% of the female mountain pine beetles found grouped under the bark of ponderosa pine contained spermatozoa just prior to emergence. Within three days after emergence into standard collection jars, 15% of these same populations contained sperm. Mating in the jars is suspected.

McCambridge, W. F. 1969. Incidence of sperm in emerging female mountain pine beetles. USDA For. Serv. Res. Note RM-137, 3 pp.

ABSTRACT

Approximately 15 percent of female mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), examined during the normal brood emergence period from field-infested ponderosa pine contained spermatozoa. In laboratory tests where parent females were accounted for, less than 2 percent of brood females contained sperm.

McCambridge, W. F. 1971. Temperature limits of flight of mountain pine beetle (*Dendroctonus ponderosae*). Ann. Entomol. Soc. Am. 64:534-5.

McCambridge, W. F. 1972. Treatment height for mountain pine beetles in Front Range ponderosa pine. USDA For. Serv. Res. Note RM-218, 2 pp.

ABSTRACT

Pitch tubes and intermittent blue stain are generally found about 5 feet above the highest point where significant mountain pine beetle brood is produced; thus, chemical control can be achieved by spraying to 5 feet below the highest pitch tubes.

McCambridge, W. F. 1974. Influence of low temperatures on attack, oviposition, and larval development of mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Can. Entomol. 106:979-84.

ABSTRACT

Mountain pine beetles attacked logs, mated, and constructed egg galleries slowly at 4.4°C under laboratory conditions. No eggs were deposited in 6 weeks. Attack and oviposition increased above this temperature.

Larvae of different initial sizes grew at the same rate throughout each test temperature from 4.4°C to 12.8°C. Rate of growth increased with increase in temperature. Larval growth at 2.2°C is difficult to prove because of very high mortality among smallest individuals.

McCambridge, W. F. 1974. Identifying ponderosa pines infested with mountain pine beetles. USDA For. Serv. Res. Note RM-273, 2 pp.

ABSTRACT

Trees successfully and unsuccessfully attacked by mountain pine beetles have several symptoms in common, so that proper diagnosis is not always easy. Guidelines presented here enable the observer to correctly distinguish nearly all attacked trees.

McCambridge, W. F. 1975. Scotch pine and mountain pine beetles. Green Thumb 32:87.

McCambridge, W. F. 1980. Some mountain pine beetle infestation characteristics in dwarf mistletoe-infected and uninfected ponderosa pine. USDA For. Serv. Res. Note RM-391, 2 pp.

ABSTRACT

There were no significant differences in attacks or brood production between heavily infected and uninfected trees. Total egg gallery length per unit of bark area was greater in uninfected trees.

McCambridge, W. F. 1981. Duration of effectiveness of Carbaryl in protecting ponderosa pines from attack by mountain pine beetles. UDSA For. Serv. Res. Note RM-408, 3 pp.

ABSTRACT

Two percent carbaryl spray provided minimally acceptable protection of ponderosa pines from mountain pine beetle attacks 13 months after application. At 4% strength, protection was satisfactory for 15 months, as tested by laboratory bioassay.

McCambridge, W. F. 1982. Effectiveness of thinning ponderosa pine stands in reducing mountain pine beetle-caused tree losses in the Black Hills: preliminary observations. USDA For. Serv. Res. Note RM-414, 3 pp.

ABSTRACT

Three ponderosa pine stands thinned to less than 90 square feet stem basal area per acre sustained little tree mortality from mountain pine beetle attacks, while adjacent, unthinned stands continued to be affected. These results are consistent with subjective observations that thinning dense, second-growth ponderosa pine is effective in preventing unacceptable levels of beetle-caused tree mortality in the Black Hills.

McCambridge, W. F. 1982. Field tests of insecticides to protect ponderosa pine from the mountain pine beetle (Coleoptera: Scolytidae). J. Econ. Entomol. 75:1080-2.

ABSTRACT

Individual ponderosa pines, *Pinus ponderosa* Lawson, can be protected from *Dendroctonus ponderosae* Hopkins attacks by spraying

the boles with 2% carbaryl-water suspension. Although lindane emulsion at 2% gives equal protection, numerous pitch tubes leave trees cosmetically inferior. Other dose rates and materials are considered inferior. Insecticides tested kill a broad spectrum of insects, including predators of the mountain pine beetle. Predators may have been attracted to certain insecticide formulations.

McCambridge, W. F., G. D. Amman and G. C. Trostle. 1979. Mountain pine beetle. USDA For. Serv. Insect and Disease Leafl. (revised), 7 pp.

McCambridge, W. F., F. G. Hawksworth, C. B. Edminster and J. G. Laut. 1982. Ponderosa pine mortality resulting from a mountain pine beetle outbreak. USDA For. Serv. Res. Paper RM-235, 7 pp.

ABSTRACT

From 1965 to 1978, mountain pine beetles killed 25% of the pines taller than 4.5 feet in a study area in north-central Colorado. Average basal area was reduced from 92 to 58 square feet per acre. Mortality increased with tree diameter up to about 9 inches d.b.h. Larger trees appeared to be killed at random. Mortality was directly related to number of trees per acre and presence of dwarf mistletoe, but not to site index, elevation, or percent Douglas-fir in the stand.

McCambridge, W. F., J. Laut and R. Gosnell. 1975. Fumigate firewood infested with mountain pine beetle. USDA For. Serv. Res. Note RM-289, 2 pp.

ABSTRACT

Beetles in ponderosa pine firewood can be killed by spraying each cord with 2 gallons of ethylene dibromide emulsion then covering and sealing the piles with plastic.

McCambridge, W. F. and S. A. Mata, Jr. 1969. Flight muscle changes in Black Hills beetles, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), during emergence and egg laying. Can. Entomol. 101:507-12.

ABSTRACT

The lateralis medius, an indirect flight muscle of Black Hills beetles, degenerated abruptly in females within 3 days after attack. Egg laying began at the end of the 3 days. Thickness of the muscle changed much more than width. Regeneration began in most ovipositing females about 10 days after attack. Steady development of the muscle to its maximum size, reached prior to beetle emergence, offers a method of forecasting emergence.

McCambridge, W. F., M. J. Morris, and C. B. Edminster. 1982. Herbage production under ponderosa pine killed by the mountain pine beetle in Colorado. USDA For. Serv. Res. Note RM-416, 3 pp.

ABSTRACT

Herbage growth increased steadily over 4 years, beginning the year after beetle attack. Yields of forbs, sedges, and grasses contributed most to gains of between a quarter and a half ton per acre of dry herbage. Yields of herbage were not increased in the shade of saplings where overstory trees were killed by beetles. Rapid herbage growth and the mulch provided by fallen dead pine needles appeared to help prevent soil erosion.

McCambridge, W. F. and G. C. Trostle. 1972. The mountain pine beetle. USDA For. Serv., For. Pest Leaflet 2, 6 pp. (rev.)

McClelland, W. T., F. P. Hain, C. J. DeMars, W. S. Fargo, R. N. Coulson and T. E. Nebeker. 1978. Sampling bark beetle emergence: A review of methodologies, a proposal for standardization, and a new trap design. Bull. Entomol. Soc. Am. 24:137-40.

McCord, P. O. and C. L. Massey. 1948. Black Hills insect control project - 1948. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO.

McGhehey, J. H. 1968. Territorial behavior of bark-beetle males. Can. Entomol. 100:1153.

* McGhehey, J. H. 1969. Sex ratios of individual broods of the mountain pine beetle. Bi-Mon. Res. Notes, Ottawa 25:2.

* McGhehey, J. H. 1971. Female size and egg production of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, N. For. Res. Cent., Edmonton, Alberta, Inf. Rept. NOR-X-9, 18 pp.

McGregor, M. D. 1972. Effect of thinning second-growth ponderosa pine on incidence of mountain pine beetle infestation - Establishment Report. USDA For. Serv. Northern Reg., Rept. No. I-72-3, 5 pp.

* McGregor, M. D. 1973. Status of mountain pine beetle, Gallatin Ranger District, Gallatin National Forest. USDA For. Serv., Northern Reg., Rept. No. 73-9.

McGregor, M. 1973. Cultural control of mountain pine beetle in second-growth ponderosa pine stands, Lolo National Forest. USDA For. Serv., Northern Reg., Rept. No. 73-14, 6 pp.

* McGregor, M. D. 1974. Status of mountain pine beetle infestations, Gallatin District, Gallatin National Forest - 1973. USDA For. Serv., Northern Reg., Rept. No. 74-17, 12 pp.

* McGregor, M. D. 1978. Status of mountain pine beetle infestations, Kootenai National Forest, Montana, 1977. USDA For. Serv., Northern Reg., Rept. No. 78-8, 12 pp.

McGregor, M. D. 1978. Management of mountain pine beetle in lodgepole pine stands in the Rocky Mountain Area. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 129-39.

ABSTRACT

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is the primary bark beetle influencing management of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann). Management by chemical treatment and by felling and burning of infested trees or salvage logging are rearguard techniques and do not prevent or reduce anticipated tree mortality. Methods are available for risk rating susceptible stands so management can be directed toward highest hazard stands. Characteristics such as slope, aspect, elevation, tree diameter, percent of lodgepole pine basal area with mistletoe infection, percent of lodgepole pine basal area in the stand and habitat type should be considered when risk rating stands. Suggested management strategies are discussed for areas designated for timber production, for individual trees of high value and for non-timber values.

McGregor, M. D. 1979. A demonstration of lodgepole pine management to prevent mountain pine beetle outbreaks, Yaak and Thompson River Drainages. Progress Report. USDA For. Serv., Northern Reg. Rept. No. 79-14, 3 pp.

McGregor, M. D. 1982. The current situation of the mountain pine beetle in the United States and the resources involved. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 16-21.

McGregor, M. D. 1985. Concepts for evaluating susceptibility of managed stands. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv., Gen. Tech. Rept. INT-174, pp. 30-1.

McGregor, M. D. 1985. Soil and Water Quality. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv., Gen. Tech. Rept. INT-174, pp 44.

McGregor, M. D. 1985. Landscape and visual management concerns. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp 44.

McGregor, M. D., G. D. Amman, and W. E. Cole. 1981. Hazard rating lodgepole pine for susceptibility to mountain pine beetle infestation. In R. L. Hedden, S. J. Barras, and J. E. Coster (eds.). Hazard rating systems in forest pest management. USDa For. Serv. Gen. Tech. Rept. WO-27, pp. 99-104.

ABSTRACT

Montana stands of lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were rated using Amman's system for risk of infestation by mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Hazard rating was based on three factors--climate suitability of the stand, average d.b.h., and average tree age. The system helped direct land managers to susceptible stands where harvest of trees is reducing losses to the beetles. During the 5 years following rating, 11 percent of the high-hazard stands became infested; only 1 percent of the stands rated moderate became infested; and less than 1 percent of the stands rated light became infested.

* McGregor, M. D., W. E. Bousfield, R. D. Lood and H. E. Meyer. 1974. Mountain pine beetle impact survey Ninemile Drainage, Lolo National Forest, and State and private lands, Montana - 1973. USDA For. Serv., Northern Reg., Rept. No. 74-22, 8 pp.

McGregor, M. D. and D. M. Cole. 1985. Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, 68 pp.

ABSTRACT

Guidelines are presented to assist forest managers in integrating pest management techniques for the mountain pine beetle *(Dendroctonus ponderosae* Hopk. with other resource considerations in the process of planning and executing balanced resource management of lodgepole pine *(Pinus contorta* var. *latifolia)* forests. The guidelines summarize published and unpublished technical information and recent research on the ecological interaction of pest and host and present visual and classification criteria and methods for recognizing and summarizing occurrence and susceptibility status of lodgepole pine stands according

to habitat types and successional roles and important resource considerations associated with them. Information is summarized for appropriate silvicultural systems and for practices that address significant resource concerns of commercial and noncommercial forest land designations and wilderness and other special administrative areas. A data acquisition, data analysis, and decision framework is presented for integrating management of mountain pine beetle populations with multiple resource management of lodgepole pine forests.

McGregor, M. D. and D. M. Cole. 1985. Integrating pest management for the mountain pine beetle with management for multiple-resource goals. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 60-2.

McGregor, M. D. and D. M. Cole. 1985. Practices and considerations for noncommercial forests. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 56-9.

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* McGregor, M. D., D. R. Hamel, R. C. Lood, H. E. Meyer and S. Kohler. 1975. Evaluation of mountain pine beetle infestations, Lazier and Meadow Creek Drainages, Plains District, Lolo National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. No. 75-17, 11 pp.

* McGregor, M. D., D. R. Hamel, H. Meyer and R. Lood. 1975. Evaluation of a mountain pine beetle infestation, Fisher River Ranger District, Kootenai National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 75-2.

* McGregor, M. D., D. R. Hamel and R. C. Lood. 1976. Evaluation of mountain pine beetle infestation, Gallatin Ranger District, Gallatin National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. 76-5, 11 pp.

* McGregor, M. D., D. R. Hamel and R. D. Oakes. 1977. Evaluation of mountain pine beetle infestations, Thompson River Drainage, Plains District, Lolo National Forest, Montana, 1976. USDA For. Serv., Northern Reg., Rept. No. 77-5, 8 pp.

* McGregor, M. D. , D. R. Hamel and R. D. Oakes. 1977. Status of mountain pine beetle infestations, Gallatin National Forest--1976. Northern Reg., Rept. No. 77-12, 8 pp.

* McGregor, M. D. and S. Kohler. 1973. Evaluation of mountain pine beetle infestation Wolf Mountains, Crow Indian Reservation, Montana, 1973. USDA For. Serv., Northern Reg., Rept. No. 73-28, 5 pp.

* McGregor, M. D., S. Kohler and G. Ferry. 1974. Evaluation of mountain pine beetle infestations, Wolf Mountains, Crow Indian Reservation, Montana, 1973. USDA For. Serv., Northern Reg., Rept. No. 74-6, 7 pp.

* McGregor, M. D. and R. C. Lood. 1970. Evaluation of bark beetle infestations Judith, Musselshell, and Belt Creek Ranger Districts, Lewis and Clark National Forest, Montana. USDA For. Serv., Northern Reg., 4 pp.

* McGregor, M. D. and R. C. Lood. 1973. Status of bark beetle infestations in second-growth ponderosa pine stands, Bureau of Land Management lands, Garbet Mountains, Montana. USDA For. Ser., Northern Reg., Rept. No. 73-25, 5 pp.

* McGregor, M. D. and H. E. Meyer. 1973. Evaluation of mountain pine beetle infestations, Big Belt Mountains, Townsend District, Helena National Forest--1973. USDA For. Serv., Northern Reg., Rept. No. 73-29, 5 pp.

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* McGregor, M. D. and S. Tunnock. 1971. Status of mountain pine beetle infestations on the Hebgen Lake Ranger District, Gallatin National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 71-45.

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ABSTRACT

The male stridulatory apparatus of six *Dendroctonus* bark beetles is described, showing species-specificity especially in the elytral files. Typical male stridulation of *D. Pseudotsugae* and *D. ponderosae* at the chemostimulus of each female's attractant and at stress when handled, is found to be distinct and specific when electronically recorded.

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Mitchell, R. G., R. H. Waring, and G. B. Pitman. 1983. Thinning lodgepole pine increases tree vigor and resistance to mountain pine beetle. For. Sci. 29:204-11.

ABSTRACT

Thinned and unthinned stands of lodgepole pine in eastern Oregon were evaluated in 1980 to determine their vigor and susceptibility to attack by outbreak populations of the mountain pine beetle. Application of a vigor rating system, based on amount of stem growth per square meter of crown leaf area, showed that thinnings from below improved vigor of residual stand and reduced beetle attack. Beetle mortality was significant in unthinned and lightly thinned stands where current annual growth of stemwood of residual trees averaged less than 80 g/m^2 of foliage. Stands with mean vigor ratings of about 100 were beginning to suffer beetle attack. There was no mortality in heavily thinned stands where vigor ratings exceeded 120. These findings suggest that lodgepole pine can be managed through stocking control to obtain fast-growing large-diameter trees and to avoid attack by the mountain pine beetle.

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Moeck, H. A., D. L. Wood and K. O. Lindahl, Jr. 1981. Host selection behavior of bark beetles (Coleoptera: Scolytidae) attacking *Pinus ponderosa*, with special emphasis on the western pine beetle, *Dendroctonus brevicomis*. J. Chem. Ecol. 7:49-83.

ABSTRACT

Detection of weakened hosts from a distance by bark beetles through olfaction was investigated in field experiments. No significant memebers of Scolytidae were attracted to anaerobically treated pine bolts, stem disks, or sugar and ponderosa pine bark including phloem. Treatment of living trees with cacodylic acid induced attacks by *Dendroctonus brevicomis*, *D. ponderosae*, *Ips latidens*, *Gnathotrichus retusus*, and *Pityophthorus scalptor*, beginning two weeks after treatment. There was no significant difference between landing rates of *D. brevicomis* and *D. ponderosae* on screened treated trees and screened controls. There was a significant increase in landing rates of *G. retusus* and *I. latidens*, because both species had penetrated the screen and produced pheromones. Tree frilling alone did not increase the landing rate of bark beetles. Freezing of the lower trunk with dry ice did not increase significantly the landing rate of *D. brevicomis*, *D. ponderosae*, *G. retusus*, or *I. latidens* on screened trees, whereas

unscreened frozen trees were attacked by all four species. There was no significantly higher landing rate by *D. brevicomis, D. ponderosae, I.*

Mogren, E. W. 1956. Silvical factors influencing resistance of ponderosa pine in Black Hills beetle attack. Proc. Soc. Am. For., 1955, pp. 61-3.

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Murray, J. G. 1982. A case study. The mountain pine beetle in the East Kootenays. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/ USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 77-81.

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Nan Brownell Pirnack. 1979. Front Range Vegetation Management Project - Final Report. Nan Crownell Pirnack NewsSystems, Boulder, Colorado, 24 pp.

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Nijholt, W. W., L. H. McMullen and L. Safranyik. 1980. Pine oil prevents mountain pine beetle attack on living lodgepole pine trees. Env. Can., Can. For. Serv. Bi-mon. Res. Notes 36:1-2.

ABSTRACT

Pine oil, a by-product of sulphate wood pulping, protected pheromone-baited, living Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.), and spruce (*Picea glauca* (Moenen) Voss - *P. engelmannii* Parry hydribds) from attack by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), mountain pine beetle (*D. ponderosae* Hopk.), and spruce beetle (*D. rufipennis* (Kirby)), respectively. Pine oil also protected surrounding trees and reduced attack incidence on Douglas-fir, lodgepole pine, and spruce within at least a 10 m radius. *a*-Terpineol, one of the constituents of the pine oil mixture, was less effective.

Nijholt, W. W., L. H. McMullen and L. Safranyik. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera:Scolytidae). Can. Entomol. 113:337-40.

ABSTRACT

Pine oil, a by-product of sulphate wood pulping, protected pheromone-baited, living Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.) and spruce (*Picea glauca* (Moench) Voss - *P. engelmannii* Parry hybrids) from attack by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), mountain pine beetle (*D. ponderosae* Hopk.), and spruce beetle (*D. rufipennis* (Kirby)), respectively. Pine oil also protected surrounding trees and reduced attack incidence on Douglas-fir, lodgepole pine, and spruce within at least a 10 m radius, a-Terpineol, one of the constituents of the pine oil mixture, was less effective.

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ABSTRACT

The emergence of the Mountain Pine Beetle during August and September was gradual. The majority emerged three weeks after the first flight. Surrounding trees were heavily attacked during this period.

O'Neil, Curtis G. 1983. Mountain pine beetle in lodgepole pine (update)., Roaring Fork and North Fork drainages, Little Snake River, Medicine Bow National Forest, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-83-5, 4 pp.

O'Neil, C. G. 1984. Mountain pine beetle biological evaluation, Mosier Gulch, Clear Creek drainage, BLM, Buffalo, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-84-1, 17 pp.

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Parker, D. L. 1973. Trends of mountain pine beetle outbreaks in mixed stands of preferred hosts. USDA For. Serv., Ogden, UT., 4 pp.

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ABSTRACT

Yearly trends of a mountain pine beetle (*Dendroctonus ponderosae* Hopk.) infestation were measured in a 640-acre lodgepole pine (*Pinus contorta* Dougl.) tract in Yellowstone National Park. Before infestation the tract had 211 live trees per acre 5 inches d.b.h. and larger. A seven-year outbreak killed 56 trees per acre, the peak mortality of 27 trees per acre occurring in the fourth year.

* Parker, D. L. 1976. Biological Evaluation. Mountain pine beetle in ponderosa pine. North Kaibab Ranger District, Kaibab National Forest, Arizona, 1975. USDA For. Serv., Southwestern Reg., Rept. No. R3-76-4, 7 pp.

* Parker, D. L. 1977. Biological Evaluation. Mountain pine beetle in ponderosa pine, North Kaibab Ranger District, Kaibab National Forest, Arizona, 1976. USDA For. Serv., Southwestern Reg., Rept. No. R3-77-3, 8 pp.

Parker, D. L. 1978. Detection and evaluation surveys for the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 125-8.

ABSTRACT

Detection and evaluation surveys are conducted by survey entomologists to gain information for advising resource managers on the need, feasibility and justification for control of damaging insect infestations. This evaluation process involves aerial and ground detection surveys and the following evaluation surveys: estimation of tree damage, determination of the relative abundance of the pest, and estimation of forest susceptibility. The survey techniques commonly used by survey entomologists to detect and evaluate mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations are discussed.

Parker, D. L. 1980. Integrated Pest Management Guide. Mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in ponderosa pine, Kaibab Plateau, Arizona. USDA For. Serv., Southwestern Reg., Rept. No. R3 80-8, 12 pp.

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Parker, D. L. and D. W. Davis. 1971. Feeding habits of *Corticeus substiatus* (Coleoptera: Tenebrionidae) associated with mountain pine beetle in lodgepole pine. Ann. Entomol. Soc. Am. 64:293-4.

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ABSTRACT

A moderate mountain pine beetle infestation was characterized in standing and downed trees by low attack density, normal egg gallery length, and normal egg numbers. Larger trees produced more brood per unit surface area than smaller trees, and were infested to a greater height. Felled trees were attacked as heavily as standing trees. Trap trees might be used here to augment other beetle management approaches.

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* Patterson, J. E. 1927. Progress report of the status of the mountain pine beetle, Season of 1926. Stanford Univ., Palo Alto, CA.

* Patterson, J. E. 1927. Studies of the mountain pine beetle, *Dendroctonus monticolae*, in lodgepole pine infestations, Season of 1927. Stanford Univ., Palo Alto, CA.

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* Patterson, J. E. 1928. Experiments with the mountain pine beetle in the prevention of attacks and killing of broods. Stanford Univ., Palo Alto, CA.

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* Patterson, J. E. 1934. Epidemic of *Dendroctonus monticolae* resulting from broods breeding in sugar pine slash. Big Creek Basin, Stanislaus National Forest, California. USDA Bur. Entomol., Berkeley, CA.

* Patterson, J. E. 1934. Preliminary results of oil treatment of ponderosa pine infested with *D. brevicomis* and of sugar pine infested with *D. monticolae*. EWC field studies, Stanislaus National Forest. USDA Bur. Entomol., Berkeley, CA.

* Peterman, R. M. 1974. Some aspects of the population dynamics of the mountain pine beetle, *Dendroctonus ponderosae*, in lodgepole pine forests of British Columbia. Ph.D. Thesis, Univ. of British Columbia, Vancouver, 208 pp.

Peterman, R. M. 1977. An evaluation of the fungal inoculation method of determining the resistance of lodgepole pine to mountain pine beetle (Coleoptera: Scolytidae) attacks. Can. Entomol. 109:443-8.

ABSTRACT

Field tests were made of the fungal inoculation method of Reid *et al.* which assesses the potential of individual lodgepole pine trees (*Pinus contorta* Dougl. var. *latifolia* Engelm.) to resist attacks by mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Four hundred and eighty-four trees were inoculated with one of the beetle's mutualistic blue-staining fungi (*Europhium clavigerum* Robinson and Davidson), tree responses were determined, and the potential of each tree to resist *D. ponderosae* was predicted. Two months later, after mountain pine beetles had attacked some of these same trees, most of the predictions based on the fungal assay system proved to be incorrect. Most of the trees which were attacked and which had been rated potentially resistant did not

prevent successful bark beetle reproduction. These results, contrary to those of Shrimpton and Reid, suggest that some improvement is needed in the fungal assay method of assessing resistance of lodgepole pine to mountain pine beetle. Measures of tree resistance based on success of mountain pine beetle reproduction showed no difference in the proportion of nonresistant trees between epidemic and endemic areas.

Peterman, R. M. 1978. The ecological role of mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range. Exp. Sta., Univ. of Idaho, Moscow, pp. 16-26.

Pfister, R. D. and D. M. Cole. 1985. The host. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 7-28.

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ABSTRACT

Synthetic *trans*-verbenol containing 6% *cis*-verbenol and 1% unknowns combined with alpha-pinene was highly attractive to in-flight mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Alpha-pinene was the most active of the terpenes tested with *trans*-verbenol. Myrcene showed intermediate activity, while limonene and 3-carene apparently were ineffective in eliciting a response. As behavior-regulating chemicals, *trans*-verbenol and alpha-pinene were effective in manipulating the host selection patterns of *D. ponderosae*. When 725 mature white pines, distributed over eight 40-acre plots in northern Idaho, were baited with the 2 materials, 133 or 18% were attacked heavily and subsequently killed. Beetle attacks were noted on an additional 13% of the baited trees, but these were aborted without tree mortality. Prior to baiting, all trees were sprayed to a height of about 20 ft. with a 2.3% solution of lindane. The mortality of sprayed trees suggested that lindane

was not effective under the conditions of this study. Only 21 of the estimated 7200 unbaited mature pines within the boundaries of the study plots were mass attacked, and 11 of these trees were within 10 to 15 ft of baited mass-attacked trees.

Paperboard cylinders, about 2 ft x 10 in., covered with a tacky substance and baited with *trans*-verbenol and alpha-pinene appeared effective as a means of deadtrapping *D. ponderosae*. An abnormally high attack density could not be induced on a white pine baited with a massive amount of *trans*-verbenol and alpha-pinene.

Pitman, G. B., M. W. Stock and R. C. McKnight. 1978. Pheromone application in mountain pine beetle/lodgepole pine management: Theory and practice. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 165-73.

ABSTRACT

This report reviews two uses of pheromones to effect bark beetle population changes, mass trapping and protection of susceptible host trees by disruption of host selection and colonization. A number of theoretical tactics using pheromones for suppression and protection of lodgepole pine against the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) are discussed. From these tactics, application of the aggregative pheromone pondelure to high-risk trees scheduled for harvest is presently feasible. Current limitations to employing pheromones in mountain pine beetle/lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) management programs are attributed to large areas of undermanaged lodgepole pine, the high and extensive level of present mountain pine beetle epidemics, and the need for more research to identify and evaluate additional behavior regulators functioning in the pest's chemical communication system. Recent research, however, has clearly demonstrated the high potential for pheromone use in mountain pine beetle control programs.

Pitman, G. B. and J. P. Vité. 1969. Aggregation behavior of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) in response to chemical messengers. Can. Entomol. 101:143-9.

ABSTRACT

Populations of *Dendroctonus ponderosae* Hopk. aggregate on pine trees in response to a combination of host- and insect-produced volatiles. Release of the insect-generated volatiles by defecation coincides with the release of host volatiles as resin exudes from the galleries initiated by the female beetle. When tested with oleoresin under field conditions, synthetic *trans*-

verbenol, the major insect pheromone, was highly attractive to both sexes of *D. ponderosae*. Also, emergent female *Dendroctonus brevicomis* Lee. and *Dendroctonus frontalis* Zimm. crushed to powder at -70°C were attractive; emergent females of both species are known to contain large amounts of *trans*-verbenol. *Trans*-verbenol *per se*, however, was not attractive to walking or flying *D. ponderosae*.

Pitman, G. B., J. P. Vitè, G. W. Kinzer and A. F. Fentiman, Jr. 1968. Bark beetle attractants: *Trans*-verbenol isolated from *Dendroctonus*. Nature 218:168-9.

Pitman, G. B., J. P. Vite, G. W. Kinzer and A. F. Fentiman, Jr. 1969. Specificity of population-aggregating pheromones in *Dendroctonus*. J. Insect Physiol. 15:363-6.

ABSTRACT

In *Dendroctonus* the production of population-aggregating pheromones is not specific to sex or species. Aggregation is largely maintained by the specificity of olfactory receptor systems.

Pollack, R. and J. Pollock. 1977. The pine killer. Colo. Outdoors. 26:41-4.

Powell, J. M. 1961. The mountain pine beetle, *Dendroctonus monticolae* Hopk. in Western Canada. Can. Dept. Agr., For. Entomol. and Pathol. Br., Calgary, Alberta, Int. Rept. May.

Powell, J. M. 1966. Distributions and outbreaks of *Dendroctonus ponderosae* Hopk. in forests of Western Canada. Dept. of For., For. Res. Lab., Calgary, Alberta, Inform. Rept. A-X-2, 19 pp.

Powell, J. M. 1967. A study of habitat temperatures of the bark beetle *Dendroctonus ponderosae* Hopkins in lodgepole pine. Agr. Met. 4:189-201.

ABSTRACT

Temperatures were measured at the bark surface and in the subcortical zone of *Pinus contorta* Douglas var. *latifolia* Engelm. infested by *Dendroctonus ponderosae* Hopkins and compared with similar measurements in non-infested trees and with air temperatures. Subcortical temperatures were higher at night but usually lower during the day than air temperatures. Surface bark temperatures were intermediate. Temperatures were lower at the 1-ft level than at higher levels. Highest subcortical temperatures occurred on the south aspect; daily maxima were later in the day and daily range was greater in infested than in non-infested trees, especially during the late stages of beetle brood development. Thin-bark trees had higher temperatures and less temperature lag than thick-bark trees. Temperatures were 5.5 to 7.5°C higher under maritime tropical than maritime polar air. The effects of temperature on various aspects of beetle behavior, development and survival are discussed. Approximately 8.340 degree-hours above 10°C were required in the subcortical zone for the beetle to develop from egg to teneral adult.

Powell, J. M. 1969. Historical study of the relation of major mountain pine beetle outbreaks in Western Canada to seasonal weather. Can. For. Serv., For. Res. Lab., Calgary, Alberta, Inform. Rept. A-X-23, 11 pp.

Raffa, K. F. and A. A. Berryman. 1980. Gustatory cues in the orientation of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) to host trees. Can. Entomol. 114:97-104.

ABSTRACT

Female mountain pine beetles, *Dendroctonus ponderosae* Hopkins, were exposed to papers soaked in outer bark extracts of lodgepole pine, *Pinus contorta* Douglas var. *latifolia* Engelmann. Both benzene and methanol-water extracts elicited greater feeding activity than did controls. Non-polar host compounds exhibited greater incitant (initiation of feeding) properties, while polar compounds were more powerful stimulants (continuation of feeding). No differences were detected in feeding on extracts from resistant or susceptible trees. Repellency appears to be associated with beetle responses to active host metabolism.

Raffa, K. F. and A. A. Berryman. 1980. Flight responses and host selection by bark beetles. In A. A. Berryman and L. Safranyik (eds.). Proc. 2nd IUFRO Conf. on dispersal of forest insects: evaluation, theory and management implications. Wash. St. Univ. Coop. Ext. Serv., Pullman, Wash., pp. 213-33.

Raffa, K. F. and A. A. Berryman. 1982. Physiological differences between lodgepole pines resistant and susceptible to the mountain pine beetle and associated microorganisms. Env. Entomol. 11:486-92.

ABSTRACT

Lodgpeole pines, *Pinus contorta* Douglas var. *latifolia* Engelmann, were assayed for traits associated with resistance to the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). There was no relationship between resistance and the daily rate of resin flow, rate of resin crystallization, monoterpene content, monoterpene composition, or current growth rate. The major difference between trees which survived or died during exposure to naturally occurring high beetle populations was the extent of their active response to fungal invasion. Resistant trees responded to artifical inoculation with fungi vectored by *D. ponderosae* by forming greater quantities of resin than did susceptible trees. This wound response is general in nature, quantitatively variable, metabolically active, rapid, and localized. It appears to form the major line of defense to *D. ponderosae* and its associated fungi, and to be related to the general vigor of the tree. The wound response was greatest in those trees which had a periodic growth ratio greater than unity.

Raimo, B. J. and D. M. Haneman. 1981. An evaluation to determine the susceptibility of lodgepole pine to mountain pine beetle infestation in the Dunoir Special Management Unit. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-6, 5 pp.

Rasmussen, L. A. 1972. Attraction of mountain pine beetles to small-diameter lodgepole pines baited with *trans*-verbenol and alpha-pinene. J. Econ. Entomol. 65:1396-9.

ABSTRACT

Lodgepole pines, *Pinus contorta* Douglas, 8.9 in. diameter at breast height (DBH) or less, were baited with the pheromone *trans*-verbenol and the terpene alpha-pinene to determine if populations of *Dendroctonus ponderosae* Hopkins could be attracted to these trees of small diameter. Even though the beetles in most cases did not successfully attack baited trees, such trees were usually the first to be attacked. This phenomenon indicated that these chemicals might be used to attract beetles into areas with baited trees but not in baited trees exclusively. This indication was supported by the fact that the beetles successfully attacked larger unbaited trees.

Rasmussen, L. A. 1974. Flight and attack behavior of mountain pine beetles in lodgepole pine of Northern Utah and Southern Idaho. USDA For. Serv. Res. Note INT-180, 7 pp.

ABSTRACT

Temperature appears to be the most important factor influencing flight and attack behavior of the mountain pine beetle *(Dendroctonus ponderosae* Hopk.). To a large extent, temperature governs onset, daily time and length of emergence and flight, and location of initial attack. The optimum temperature range for adult mountain pine beetle activity extends from about 19°C to about 32°C; higher or lower temperatures limit beetle activity. Even though the sex ratio of attacking beetles favored the female in this study, all females were mated within at least 10 days of a mass attack on lodgepole pine *(Pinus contorta* Dougl.). Mated females constructed galleries at a greater rate than unmated females.

Rasmussen, L. A. 1976. Keys to common parasites and predators of the mountain pine beetle. UDA For. Serv. Gen. Tech. Rept. INT-29, 4 pp.

Rasmussen, L. A. 1980. Emergence and attack behavior of the mountain pine beetle in lodgepole pine. USDA For. Serv. Res. Note INT-297, 7 pp.

ABSTRACT

Factors influencing the behavior of mountain pine beetles infesting lodgepole pine were studied during 1974 and 1975. More and larger beetles emerged from trees having thickest phloem, with the largest beetles usually emerging first. Beetles emerging in 1974 constructed more gallery and laid more eggs than did beetles emerging

in 1975, probably due to the late beetle flight in 1975 and larger size of the females. Trees that were successfully mass attacked had lower inner bark temperatures than trees unsuccessfully attacked. The sex ratio of emerging beetles was 1.52:1, females to males; for attacking beetles it was about the same, 1.50:1, but for the boring beetles it was 2.34:1.

Reid, R. W. 1955. The bark beetle complex associated with lodgepole pine slash in Alberta. I. Notes on the biologies of some Scolytidae attacking lodgepole pine slash. Can. Entomol. 87:311-23.

* Reid, R. W. 1956. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1955-1. For. Biol. Lab., Calgary, Alberta.

* Reid, R. W. 1957. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1956-9. For. Biol. Lab., Calgary, Alberta.

Reid, R. W. 1957. The bark beetle complex associated with lodgepole pine slash in Alberta. Pt. II. Notes on the biologies of several parasites. Can. Entomol. 89:5-8.

Reid, R. W. 1957. The bark beetle complex associated with lodgepole pine slash in Alberta. Pt. III. Notes on the biologies of several predators with special reference to *Enoclerus sphegeus* Fab. (Coleoptera: Cleridae) and two species of mites. Can. Entomol. 89:111-20.

Reid, R. W. 1957. The bark beetle complex associated with lodgpeole pine slash in Alberta. Pt. IV. Distribution, population densities and effects of several environmental factors. Can. Entomol. 89:437-47.

Reid, R. W. 1958. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1957-4. For. Biol. Lab., Calgary, Alberta.

Reid, R. W. 1958. Internal changes in female mountain pine beetle, *Dendroctonus monticolae* Hopk., associated with egg laying and flight. Can. Entomol. 90:464-8.

Reid, R. W. 1958. The behavior of the mountain pine beetle, *Dendroctonus monticolae* Hopk., during mating, egg laying, and gallery construction. Can. Entomol. 90:505-9.

* Reid, R. W. 1958. Nematodes associated with the mountain pine beetle. Can. Dept. of Agri., For. Biol. Env. Bimonthly Prog. Rept. 14:3

* Reid, R. W. 1960. Studies of the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins (Coleoptera: Scolytidae). Ph.D. thesis, Montana State Col., Bozeman.

Reid, R. W. 1961. Moisture changes in lodgepole pine before and after attacks by the mountain pine beetle. For. Chron. 37:368-75.

ABSTRACT

The moisture content of the outer sapwood of non-infested lodgepole pine is normally about 85 to 165 per cent of oven dry weight. In trees that have been infested by the mountain pine beetle for one year, the sapwood moisture content can be as low as 16 per cent. There is a steep moisture gradient from about 160 per cent in the outer sapwood to about 30 per cent in the heartwood. The moisture content in the centre is slightly higher than in the adjacent wood. In infested trees the sapwood moisture is greatly reduced within a year after the attack but moisture in the heartwood is not altered appreciably. Trees infested early in the season drop to a lower moisture content by fall than trees infested later in the season. In non-infested trees there is a diurnal and a seasonal moisture march; these do not occur in infested trees. The rapid moisture loss in the sapwood of infested trees is associated with blue-stain infection and successful establishment of bark beetle broods.

Reid, R. W. 1962. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk., in the East Kootenay Region of British Columbia. I. Life cycle, brood development, and flight periods. Can. Entomol. 94: 531-8.

Reid, R. W. 1962. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootanay Region of British Columbia. II. Behavior in the host, feundity, and internal changes in the female. Can. Entomol. 94:605-13.

Reid, R. W. 1963. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the East Kootenay Region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. Can. Entomol. 95:225-38.

ABSTRACT

Studies were made on the distribution and survival of the mountain pine beetle over the lower stem of lodgepole pine. The relationship between density of attack and subsequent total length of egg galleries was examined as was the relationship between number of exit holes and number of emerging beetles. The influence on brood survival of tree diameter, density of egg galleries, moisture content of the outer sapwood, lethal temperatures, resinosis in the subcortical region, predators, and parasites is described. Survival is compared between broods established during different flights in the same year. The optimum weather conditions for brood survival are discussed.

Reid, R. W. 1969. The influence of humidity on incubating bark beetle eggs. Can. Entomol. 101:182-3.

Reid, R. W. and H. S. Gates. 1970. Effects of temperature and resin on hatch of eggs of the mountain pine beetle (*Dendroctonus ponderosae*) Can. Entomol. 102:617-22.

ABSTRACT

Effects of temperature and resin on hatch of mountain pine beetle eggs were investigated. Per-cent hatch was related to total degree-hours above 40°F, the average being 5113 for 50% hatch under field conditions. Average supercooling point was 1.3°F. Higher temperatures in the freezing range were lethal with long exposure. Atmosphere saturated with volatiles from liquid resin had very little effect on egg hatch, but direct contract with liquid resin greatly reduced egg hatch.

Reid, R. W. and H. S. Gates. 1972. Relations between some physiological functions in lodgepole pine and resistance to the mountain pine beetle. Env. Can., Can. For. Serv., Northern For. Res. Cent. Inf. Rept. NOR-X-15.

ABSTRACT

Stands of lodgepole pine exhibited varying degrees of resistance to attack by the mountain pine beetle. Variations in water tension within individual trees were reflected directly in circumference expansion and contraction, particularly following periods of stress, and this characteristic was related to some extent with the incidence of successful insect attack. Growth rhythms in the tree stems were not detected and degree of starch accumulation in the bole did not appear related to the degree of tree resistance.

Reid, R. W., H. S. Whitney and J. A. Watson. 1967. Reaction of lodgepole pine to attack by *Dendroctonus ponderosae* Hopkins and blue stain fungi. Can. J. Bot. 45:1115-26.

ABSTRACT

The reaction in lodgepole pine in response to attack by *Dendroctonus ponderosae* and subsequent infection by blue stain fungi varies with the degree of resistance manifested by the tree. In both resistant and successfully attacked trees a sequence of changes, which increase in space with time, occurs in the inner bark and sapwood. In resistant trees a condition termed secondary resinosis develops which is lethal to bark beetle broods and blue stain fungi. In contrast, successfully infested trees do not exhibit secondary resinosis, and bark beetle broods and blue stain fungi survive and complete their development. In resistant trees blue stain fungi are responsible, directly or indirectly, for the extensive reaction and condition of secondary resinosis which is associated with the insect gallery. Changes in stem tissues associated with wounding are discussed.

* Renwick, J. A. A. and J. P. Vitè. 1970. Systems of chemical communication in *Dendroctonus*. Contr. Boyce Thompson Inst. 24:283-92.

* Richmond, H. A. 1931. Annual report of investigations of *Dendroctonus monticolae* Hopkins; yellow pine and lodgepole pine stands, Aspen Grove, B.C. and population and life history studies, damage and tree mortality, parasites and predators, host selection. For. Biol. Lab., Vernon, B.C.

Richmond, H. A. 1933. Host selection studies of *Dendroctonus monticolae* Hopkins in southern British Columbia. For. Chron. 9:60-1

* Richmond, H. A. 1934. Summary of season's work, Aspen Grove project. For. Biol. Lab., Vernon, B.C.

* Richmond, H. A. 1935. Studies on the mountain pine beetle, Ann. Rept. For. Entomol. Lab., Vernon, B.C.

* Richmond, H. A. 1935. A morphological study of the bark beetle *Dendroctonus monticolae* Hopk. M.S. Thesis, McGill Univ., Montreal, Quebec.

Robinson, R. C. 1962. Blue stain fungi in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) infested by the mountain pine beetle (*Dendroctonus monticolae* Hopk.) Can. J. Bot. 40:609-14.

ABSTRACT

A complex of fungi was isolated from lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) at various stages of mountain pine beetle (*Dendroctonus monticolae* Hopk.) attack. *Ceratocystis montia* Rumb., *Leptographium* sp., *Pichia pini* (Holst) Phaff, *Hansenula holstii* Wickerham, *Hansenula capsulata* Wickerham, and some unnamed yeasts were isolated from beetles, fresh galleries, and blue-stained sapwood. Perithecia of *C. monia*, *Ceratocystis minor* (Hedge.) Hunt, *Ceratocystis minuta* (Siem.) Hunt, *Ceratocystis* sp., and *Europhium* sp. were found on the bark and sapwood of dead, blue-stained trees. Beetles are conclusively shown to be vectors

of blue stain fungi. The known ranges of *C. montia* and *P. pini* are extended by this study and a possible succession of organisms associated with the development of beetle infestation is discussed.

Roe, A. L. and G. D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv. Res. Paper INT-71, 23 pp.

ABSTRACT

The mountain pine beetle depletes Rocky Mountain lodgepole pine stands by removing periodically the largest, most vigorous trees. Some stands are replaced by succeeding species in 80 to 100 years.

Intensities of mountain pine beetle and dwarf mistletoe damage are influenced by forest associations and elevation. Dwarf mistletoe infection reduced phloem depth and probably results in lower mountain pine beetle brood production.

The probability of lodgepole pine surviving to 16 inches d.b.h. is about two out of three in the *Abies lasiocarpa/Vaccinium scoparium* association, but only one out of four in the *Abies lasiocarpa/Pachistima myrsinites* association. The latter association offers the greatest risk to lodgepole pine. More effective beetle control and alternatives such as type conversion, shorter rotations, mixing species, and developing better size and age class distribution must be considered.

* Ross, D. A. 1957. A preliminary report on appraisal of the amount of timber killed by bark beetles of the genus *Dendroctonus*. Interior B.C. Can. Dept. Agr., For. Biol. Lab., Vernon, B.C., Int. Rept. 1956-2.

Ross, D. A. 1965. Control of mountain pine beetle, *Dendroctonus ponderosae* Hopk., brood in logs with lindane emulsion. Proc. Entomol. Soc. B.C. 62:8-10.

Rost, M. T. 1978. Comments on the mountain pine beetle/lodgepole pine symposium. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 205-7.

ABSTRACT

The questions of what managers need from researchers and the extent to which this symposium met that need are discussed. The importance of preventive programs is emphasized. Ways in which managers can become more involved in solving the problem of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are suggested.

Rudinsky, J. A. and R. R. Michael. 1973. Sound production in Scolytidae: stridulation by female *Dendroctonus* beetles. J. Insect Physiol. 19: 689-705.

Rudinsky, J. A., M. E. Morgan, L. M. Libbey, and T. B. Putnam. 1974. Antiaggregative-rivalry pheromone of the mountain pine beetle, and a new arrestant of the southern pine beetle. Env. Entomol. 3:90-8.

ABSTRACT

Eight pheromones were collected as volatiles from living *Dendroctonus* beetles, and identified by GLC/MS. With *Dendroctonus frontalis* Zimmerman, in addition to earlier reported pheromones, the monoterpene ketone pinocarvone, and frontalin, were released by males, and the terpene alcohol myrtenol was released by both males and females. With *D. ponderosae* Hopkins, besides the previously known pheromones, *endo*-brevicomin and 3-methyl-2-cyclohexen-1-one (MCH) were released by males, and frontalin was collected from pairs of this species. Bioassay indicated that *exo*-brevicomin with *D. ponderosae*, and myrtenol as well as verbenone with *D. frontalis*, are multifunctional pheromones, since a small quantity (released by females) was synergistically attractive, and a larger quantity (released by males) was pressive and/or evoked "rivalry" behavior. For this latter effect, the male pheromones were designated antiaggregative-this species releases no inhibitor and depends upon host oleoresin effects to stop beetle aggregation. The identified male pheromones were released with males placed together, as well as with pairs, and the pheromones of female *D. frontalis* (though not of female *D. ponderosae*) were also released with females placed together, as well as with pairs. Both intrasex and intersex stimuli and response must be important in pheromone release, and may help answer certain questions about bark beetle behavior of practical significance in attempts to utilize these pheromones in control.

Rumbold, C. T. 1941. A blue stain fungus *Ceratostomella montium* n. sp. and some yeasts associated with two species of *Dendroctonus*. J. Agr. Res. 62:589-601.

* Rust, H. J. 1929. Preliminary Report on the effectiveness of the peeling method of control relative to the destruction of *Dendroctonus* broods. USDA Bur. Entomol., Coeur d'Alene, ID.

* Rust, H. J. 1929. Relation of insectivorous birds to the mortality of the mountain pine beetle during flight period. UDSA Bur. Entomol., Coeur d'lene, ID.

* Rust, H. J. 1930. Relation of insectivorous birds to mortality of the mountain pine beetle during flight period. USDA Bur. Entomol. Coeur d'Alene, ID.

* Rust, H. J. 1931. Final report on the role of ants, centipedes, and rodents destructive to broods of the mountain pine beetle exposed by the peeling method of control. USDA Bur. Entomol., Coeur d'Alene, ID.

* Rust, H. J. 1933. Many bark beetles destroyed by predacious mites. J. Econ. Entomol. 26:773-4

Rust, H. J. 1935. The role of predatory agents in the artificial control of the mountain pine beetle. J. Econ. Entomol. 28:688-91.

Ryker, L. C. and J. A. Rudinsky. 1976. Sound production in scolytidae: Aggressive and mating behavior of the mountain pine beetle. Ann. Entomol. Soc. Am. 69:677-80.

ABSTRACT

Dendroctonus ponderosae Hopkins males emitted interrupted chirps both while fighting a rival male and when attracted into a

virgin female's gallery. Behavior accompanying interrupted chirps was aggressive in both contests. Females became silent and permitted entry when chirping males touched them, but chirped continuously, attacked, and usually ejected surgically silenced males, indicating a premating recognition function for the interrupted chirp nonaggressive, courting behavior occurred in the gallery as stridulation changed to simple, uninterrupted chirps just before mating. Females responded to stridulation at the gallery entrance by simple, multi-impulse chirps similar to the territorial chirp reported earlier. The chirp is not emitted during courtship and appears be mainly a territorial response to intruders. Phonostimulus of acoustic response between the 2 sexes, in addition to the previously shown olfactory response, is now established.

Ryker, L. C. and L. M. Libbey. 1983. Frontalin in the male mountain pine beetle. J. Chem. Ecol. 8:1399-1409.

ABSTRACT

Frontalin and *exo*-brevicomin were identified by GC-MS in air drawn over male *Dendroctonus ponderosae* Hopk. (MPB) from Oregon that had joined females for 1-2 days in the bark of lodgepole pine and ponderosa pine logs. Unfed males released *exo*- and *endo*-brevicomin but not frontalin. Arrestment of males by *trans*-verbenol and terpenes in an olfactory walkway was reduced by the addition of racemic frontalin; production of attractant chirps also diminished. Racemic frontalin also strongly reduced the aggregation of MPB in lodgepole and ponderosa pine stands to sticky traps baited with the aggregation pheromone *trans*-verbenol and host terpenes; however, the function of the natural enantiomer of frontalin in MPB is unknown.

* Safranyik, L. 1968. Development of a technique for sampling mountain pine beetle populations in lodgpeole pine. Ph.D. Thesis, Univ. of B.C., Vancouver, 195 pp.

Safranyik, L. 1971. Some characteristics of the spacial arrangement of attacks by the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), on lodgepole pine. Can. Entomol. 103:1607-25.

ABSTRACT

Evidence is given in support of the hypothesis that the spatial arrangement of attacks by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) on its host, lodgepole pine (*Pinus*

contorta Dougl. var. *latifolia* Engelm.), is largely determined by the pattern of bark niches suitable for attack initiation. Density of attack sites and bark thickness are important to determine the attack-harbouring potential of the bark and in determining the upper limit of attacks, thus, the potential area available for attack on the bark surface of lodgepole pine trees. At fixed levels on the clear bole of naturally infested trees, attack pattern tends to be regular owing to the regular spatial pattern of suitable attack sites. The regularity of the attack pattern is disturbed by the presence of an attack-density gradient around the stem circumference. The vertical attack-density gradient over the host is well described in terms of a relation between attack density and bark thickness. This relation is asymptotic and rests on the assumption that the density of bark niches suitable for attack initiation approaches an upper limit with increasing bark thickness on lodgepole pine trees.

Safranyik, L. 1976. Size- and sex-related emergence, and survival in cold storage, of mountain pine beetle adults. Can. Entomol. 108:209-12.

ABSTRACT

Larvae of the mountain pine beetle, *Dendroctonus ponderosae* Hopk., were reared to adults in naturally infested bolts of lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm., at 21 $\pm$ 3°C. The mean pronotal width of the emerging beetles of both sexes decreased, and the male:female ratio increased, during the emergence period. On the average, larger individuals of both sexes survived longer when adult beetles were stored at 1 $\pm$ 2°C. Also, the male:female ratio of the survivng beetles decreased with increased storage duration. These and related results in the literature suggest that in natural populations of the mountain pine beetle average adult size increases, and the male:female ratio decreases, following stress-induced mortality in the larval and(or) adult stages.

Safranyik, L. 1978. Effects of climate and weather on mountain pine beetle populations. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range. Exp. Sta., Univ. of Idaho, Moscow, pp. 77-84.

ABSTRACT

The literature on the direct effects of climate and weather on the biology and dynamics of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) populations is reviewed and discussed, with emphasis on the development of epidemics. Of the climatic effects,

temperature is the most important. Typically, in the optimum range of the beetle's distribution on lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann), there is enough heat accumulation each year to produce one or more generations and the frequency of adverse weather conditions is not high enough to prevent population build-up or to reduce infestations to endemic levels. In some years, however, adverse weather can cause a decline in population and damage levels, but this reversal is usually temporary and the course of outbreak is largely determined by factors other than climate. In this optimum habitat, the beetle poses a continuous threat to lodgepole pine of susceptible age and size. At high elevation and at northern latitudes, climate becomes the dominant factor controlling the distribution and abundance of mountain pine beetle populations and infestations in space and time. Beetle development is out of phase with the cold season; consequently, the least cold-hardy life stages (eggs, pupae) may enter the winter and suffer heavy mortality. Epidemics tend to be less frequent and intense, and stand depletion decreases, toward the limits of the distributional range. The northern limit of the beetle's range is bounded by the isotherm for -40°C (-40°F) mean annual minimum temperature and a zone where, on the average, heat accumulation during the growing season is less than the estimated minimum (833 degree-days C) for brood development on a 1-year cycle. The upper altitudinal limit, which ranges from about 750 m (2460 ft) near the northern limit (latitude 56°N) to about 3650 m (11,972 ft) near the southern limit (latitude 31°N), is probably delimited by similar temperature conditions.

Safranyik, L. 1982. Alternative solutions. Preventative management and direct control. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 29-32.

Safranyik, L. and R. Jahren. 1970. Emergence patterns of the mountain pine beetle from lodgepole pine. Dept. Fish. For., Bimonthly Res. Notes 26:11-19.

Safranyik, L. and R. Jahren. 1970. Host characteristics, brood density and size of mountain pine beetles emerging from lodgepole pine. Dept. Fish. For. Can., Bimonthly Res. Notes 26:35-6.

* Safranyik, L., D. M. Shrimpton and H. S. Whitney. 1974. Management of lodgepole pine to reduce losses from mountain pine beetle. Can. For. Serv., For. Tech. Rept. 1, 24 pp.

* Safranyik, L., D. M. Shrimptom and H. S. Whitney. 1975. An interpretation of the interaction between lodgepole pine, the mountain pine beetle and its associated blue stain fungi in western Canada. In D. M. Baumgartner (ed), Management of lodgepole pine ecosystems, Wash. St. Univ. Coop. Ext. Serv., Vol. 1, pp. 406-28.

Safranyik, L., G. A. VanSickle, and G. H. Manning. 1981. Position paper on mountain pine beetle problems with special reference to the Rocky Mountain Parks Region. Env. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C., 27 pp.

* Salman, K. A. 1933. Further tests of oil spray to control the western and mountain pine beetles. USDA Bur. Entomol., Berkeley, CA

* Salman, K. A. 1935. The composition of forest insect infestations in ponderosa pine as determined by stem analysis. USDA Bur. Entomol., Berkeley, CA

Salman, K. A. 1938. Recent experiments with penetrating oil sprays for the control of bark beetles. J. Econ. Entomol. 31:119-23.

Salman, K. A. and J. W. Bongberg. 1942. Logging high-risk trees to control insects in the pine stands of Northeastern California. J. For. 40:533-9

ABSTRACT

The problem of pine beetle control in ponderosa pine has been studied by the Bureau of Entomology and Plant Quarantine for more than thirty years. The first method of control, proposed by Hopkins in 1909 consisted of reducing bark beetle populations by felling, peeling, and burning infested trees or removing them to mills. This method of control is still in use under certain conditions, but like other methods of direct control it produces only temporary results. Consequently, members in the Bureau of Entomology and Plant Quarantine

for many years have been attempting to devise certain indirect methods to reduce losses from pine beetles. One of these indirect methods is logging high-risk trees which in the pine stands of northeastern California has given encouraging results.

Sampson, G. R., D. R. Betters, and R. W. Brenner. 1980. Mountain pine beetle, timber management and timber industry in Colorado's Front Range: production and marketing alternatives. USDA For. Serv. Res. Bull. RM-3, 8 pp.

ABSTRACT

Current harvest levels and processing capacity do not take full advantage of timber potentially available in six Front Range timbersheds. Four alternatives for utilizing this resource were analyzed using a goal programming technique. Multiproduct operations based on numerous small sawmills appear to offer the best solution.

Sampson, G. R., D. R. Betters, and R. R. Love. 1980. Insect-infected ponderosa pine and associated timber potentially available at six Colorado centers. USDA For. Serv. Res. Bull. RM-1, 6 pp.

ABSTRACT

Increased timber harvesting by forest industry, resulting in more intensive forest management, would be a means for combating insect problems such as the current mountain pine beetle outbreak. However, existing timber processing capability is far less than potential annual harvest of live timber for Colorado's Front Range.

Sartwell, C. 1969. Role of mountain pine beetle in the population ecology of ponderosa pine. Bull. Oregon. Entomol. Soc. 35:255.

Sartwell, C. 1971. Thinning ponderosa pine to prevent outbreaks of mountain pine beetle. In D. M. Baumgartner (ed.). Precommercial thinning of coastal and intermountain forests in the Pacific Northwest. Wash. St. Univ., Coop. Ext. Serv., Pullman, pp. 41-52.

ABSTRACT

Severe tree killing by *Dendroctonus ponderosae* is an increasing pest problem in second-growth *Pinus ponderosa* stands in Oregon and Washington. Particularly affected are even-aged pole stands 60 to 80 years old on poor sites. Excessive between-tree competition generally underlies the occurrence of beetle outbreaks, as infested trees typically have grown less than 1 inch in diameter during the decade prior to attack and have live crowns shorter than one-third of stem height. Severity of beetle-caused mortality is related to stand density, which indicates that thinning of dense stands will prevent beetle outbreaks.

Sartwell, C. and R. E. Dolph, Jr. 1976. Silviculture and direct control of mountain pine beetle in second-growth ponderosa pine. USDA For. Serv. Res. Note PNW-268, 8 pp.

ABSTRACT

In the first 5 years after treatment, silvicultural thinning reduced killing of *Pinus ponderosa* poletimber by *Dendroctonus ponderosae* by more than 90 percent and led to positive net stand growth in an eastern Oregon test. The felling and burning of infested trees also substantially reduced tree mortality caused by mountain pine beetle; even so, the treated stand declined in the post-treatment period due to damage by other agents. The practical effect of direct control in combination with thinning was no greater than that obtained by thinning alone.

Sartwell, C. and R. E. Stevens. 1975. Mountain pine beetle in ponderosa pine - prospects for silvicultural control in second growth stands. J. For. 73:136-40.

ABSTRACT

Mountain pine beetle is the major insect enemy of second-growth ponderosa pine in many interior areas of the western United States. Severe tree killing occurs predominately in dense stands where competition has substantially slowed growth of even the dominant trees. Experiments were begun in the 1960's to determine if beetle outbreaks can be prevented by silvicultural thinning.

Early results indicate that thinning of dense stands deserved major emphasis in efforts to minimize this pest problem.

Schenk, J. A., R. L. Mahoney, J. A. Moore, and D. L. Adams. 1980. A model for hazard rating lodgepole pine stands for mortality by mountain pine beetle. For. Ecol. and Mgmt. 3:57-68.

ABSTRACT

A stand hazard rating (SHR) was developed to rate lodgepole pine stands for tree mortality caused by the mountain pine beetle. The stand hazard rating is a function of Crown Competition Factor and percent lodgepole pine basal area, SHR = CCF * PLPP. This model can assist forest managers in assigning priorities for the application of silvicultural treatments to prevent or reduce the level of lodgepole pine mortality induced by mountain pine beetle.

* Schmid, J. M. 1968. Three insect predators of *Dendroctonus ponderosae* Hopkins. Ph.D. Diss., Univ. Mich., Ann Arbor, 180 pp.

Schmid, J. M. 1969. *Laphria gilva* (Diptera:Asilidae), a predator of *Dendroctonus ponderosae* in the Black Hills of South Dakota. Ann. Entomol. Soc. Am. 62:1237-41.

ABSTRACT

Adults of *Laphria gilva* (L.) killed about 1% of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), adults during the 1967 emergence period in the Black Hills. *L. gilva* adults commonly rest on tree trunks in *Dendroctonus*-infested areas, and capture *D. ponderosae* adults in flight. Males initiate mating from the resting position while females are hovering near the ground. Eggs are laid in the forest litter near tree bases. The predatory and ovipositional behavior are discussed in relation to predation on *D. ponderosae*.

Schmid, J. M. 1970. *Medetera aldrichii* (Diptera: Dolichopodidae) in the Black Hills. I. Emergence and behavior of adults. Can. Entomol. 102:705-13.

ABSTRACT

The number of *Medetera aldrichii* Wheeler adults emerging daily in 1966 and 1967 was low and irregular. Peak numbers apparently emerged 20-30 days prior to mass emergence of *Dendroctonus ponderosae* Hopkins although the numbers fluctuated through the mass emergence period of the beetle. Densities of emerging adults averaged less than 1 per square foot of bark and never exceeded 6.0 per square foot. Densities of the emerging flies and beetles did not appear related.

Adults mated on the bark surface of trees infested with *D. ponderosae;* mating habits are described.

Females oviposited in degenerate resin ducts in the bark surface. Two eggs per duct were the model number. Seven or more per duct were found in less than 5% of the ducts examined.

Schmid, J. M. 1970. *Enoclerus sphegeus* (Coleoptera: Cleridae), a predator of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) in the Black Hills, Can. Entomol. 102:969-77.

ABSTRACT

Enoclerus sphegeus Fabricius adults were most abundant on trees infested with *Dendroctonus ponderosae* Hopkins in May and June of 1966 and 1967. Greatest numbers of adults were observed on the bole from 0 to 5 ft. above ground, apparently in response to the activity of other scolytids. In the laboratory, each adult killed about 1 *D. ponderosae* per day, and each larva killed about 25 *D. ponderosae* during development. Mean larval densities were generally less than 0.2 per squre foot at four different sampling heights on the tree bole during the overwintering period. Densities were greatest at all heights in July. Maximum larval density was observed at the 1.5-ft height. Larvae began leaving the trees for pupation sites in July of both years. It is estimated that adult clerids consume less than 1% of the adult beetle population during their attack period and the clerid larvae kill 5-11% of the beetle brood.

Schmid, J. M. 1971. *Medetera aldrichii* (Diptera: Dolichopodidae) in the Black Hills. II. Biology and densities of the immature stages. Can. Entomol. 103:848-53.

ABSTRACT

Medetera aldrichii Wheeler larvae enter galleries of *Dendroctonus ponderosae* Hopkins through the beetle entrance holes. Observed larval densities of the fly were greatest in the May-June period following beetle attack. Densities were consistently greatest in the portion of the tree 5-10 ft. above ground; averaging around 3-4/sq. ft. The fly larvae probably cause a major share of the beetle mortality between August and the following May. The fly larvae pupate near beetle-created openings that lead from the galleries to the exterior.

Schmid, J. M. 1972. Emergence, attack densities, and seasonal trends of mountain pine beetle (*Dendroctonus ponderosae*) in the Black Hills USDA For. Serv. Res. Note. RM-211, 7 pp.

ABSTRACT

Beetles began emerging around July 1 and emerged in peak numbers on August 15, 1966 and 1967. Adults emerged almost simultaneously from the north and south sides of trees. More beetles emerged from the south side at 1.5 feet above ground than from the north side at the same height, but this relationship was reversed at heights of 5 feet and 10 feet. Densities of beetle attacks varied significantly with height and aspect. Brood densities declined drastically between the time of attack and the following May. Relationships between beetle emergence evaluation techniques, and control operations are discussed.

Schmid, J. M. 1972. A problem in the Front Range: Pine beetles. Colo. Outdoors 21:37-9.

Schmidt, W. C. 1982. Alternative solutions to mountain pine beetle: silviculture perspective. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 33-40.

* Schmitz, R. F., M. D. McGregor and G. D. Amman. 1980. Mountain pine beetle response to lodgepole pine stands of different characteristics. In A. A. Berryman and L. Safranyik (eds.). Dispersal of forest insects: evaluation, theory and management implications. Proc. of the 2nd IUFRO Conf., Wash. St. Univ., Coop. Ext. Serv. Pullman, WA, pp. 234-43.

Schafer, G. A. and G. D. Lanier. 1970. A sexual character in pupae of *Dendroctonus* (Coleoptera:Scolytidae). Can. Entomol. 102:1487-8.

Schlotz, Kenneth C. 1972. Evaluation of a mountain pine beetle infestation. USDA For. Serv., Black Hills Nat. For. Rept. 14 pp.

* Schonherr, J. 1976. Mountain pine beetle: visual behavior related to integrated control. Proc. of the XVI IUFRO World Cong., Oslo, Norway, pp. 449-52.

Sharp, R. H. and R. E. Stevens. 1962. New technique for spraying standing trees infested with bark beetles. J. For. 60:548-50.

Sharpnack, Nancy S. and John Wong. 1982. Sampling designs and allocations yielding minimum cost estimates for mountain pine beetle loss assessment surveys. USDA For. Serv., Methods Application Group, Rept. No. 83-8, 11 pp.

ABSTRACT

Tables of optimum sample size for each of three stages are presented for estimating mountain pine beetle loss in ponderosa and lodgepole pine forests in the western United States. These are listed for varying levels of precision and are based on data collected during surveys conducted between 1977 and 1980.

Shaw, D. 19__. Your forest-your decision. Colo. St. For. Serv., Colo. St. Univ., 20 pp.

* Shepherd, R. F. 1956. Population studies of the mountain pine beetle. Int. Rept. 1955-5. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta, 21 pp.

Shepherd, R. F. 1958. Population studies of the mountain pine beetle. Int. Rept. 1957-1. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta.

* Shepherd, R. F. 1959. Population studies of the mountain pine beetle. Int. Rept. 1958. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta.

* Shepherd, R. F. 1960. Distribution of the Black Hills beetle over the host tree and factors controlling the attraction and behavior of the adult. Ph.D. Thesis, Univ. Minn., Minneapolis, 82 pp.

Shepherd, R. F. 1962. Population studies of the mountain pine beetle. Int. Rept. Can. Dept. For., For. Entomol. and Pathol. Lab., Calgary, Alberta.

Shepherd, R. F. 1965. Distribution of attacks by *Dendroctonus ponderosae* Hopk. on *Pinus contorta* Dougl. var. *latifolia* Engelm. Can. Entomol. 97:207-15.

Shepherd, R. F. 1966. Factors influencing the orientation and rates of activity of *Dendroctonus ponderosae* Hopkins (Coleoptera:Scolytidae). Can. Entomol. 98:507-18.

ABSTRACT

The tactic and kinetic responses of adult *Dendroctonus ponderosae* Hopkins were studied under varying conditions of light, temperature, humidity, gravity, and with different visual forms. Newly emerged adult *Dendroctonus ponderosae* Hopk. were attracted by high light intensity and utilized spot sources of light and surrounding objects, but not polarized light, for orientation. Flying adults were positively phototactic unless warmed above 35°C; egg-laying adults were negatively phototactic. High temperatures and light intensities increased the frequency of flights. The beetles were negatively geotropic but this could be masked by the attraction to light. Dark objects on a light background were attractive; the size of the object was important while the shape was not.

Temperature influenced orientation to some extent but its influence on rate of activity was far more pronounced; rate of walk followed a linear relationship with temperature. Humidity also affected orientation and rate of walk to some extent, although its effect was usually masked by other environmental factors.

* Shepherd, R. F. and J. A. Watson. 1959. Blue stain fungi associated with the mountain pine beetle. Can. Dept. Agr., For. Bio. Div. Bi-monthly Prog. Rept. 15:2-3.

Shrimpton, D. M. 1973. Extractives associated with wound response of lodgepole pine attacked by the mountain pine beetle and associated microorganisms. Can. J. Bot. 51:527-34.

ABSTRACT

Extractive changes that occur in the sapwood of lodgepole pine *(Pinus contorta* Dougl. var. *latifolia* Englm.) in response to attack by the bark beetle *(Dendroctonus ponderosae* Hopk). and associated micro-organisms were studied. The most striking change was a large increase in total terpene to levels well above that normally observed in sapwood or heartwood. Free acids, phenolics, and neutral components increased to a final concentration about the same as that in heartwood, but at a much slower rate than terpenes. Free sugar levels decreased. With the single exception of B-phellandrene no unusually high or unusually low levels of any one compound were observed in the wound response. All components found in the wound response were normal constituents of heartwood.

Shrimpton, D. M. 1978. Resistance of lodgepole pine to mountain pine beetle infestation. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 64-76.

ABSTRACT

This paper discusses the possible relationships between the mountain pine beetle *(Dendroctonus ponderosae* Hopkins) and the physiological processes of the lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann) stem that act to heal wounds of the type caused by bark beetles. The resin canal system of lodgepole pine and production of secondary resins are described. The effects of moisture stress and the relationship of each resin system to maturation of the tree are also described. The interaction between tree response and the attacking beetle/blue stain-complex and the relationship between mountain pine beetle outbreak and physiological maturity of lodgepole pine are discussed.

Shrimpton, D. M. (ed.) 1982. Proceedings of the joint Canada/USA workshop on mountain pine beetle related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, 87 pp.

ABSTRACT

This two-day workshop on the economic and social problems related to the current mountain pine beetle epidemics in western Canada and the United States was jointly sponsored by the Canadian Forestry Service and the United States Forest Service, in cooperation with the Alberta and British Columbia Forest Services. The workshop was convened because the consequences of the extensive and widely spread epidemics are now regarded as being of crisis proportions in both countries.

In attendance from both countries were representatives from government, the forest industry, universities, National Parks, National and regional Forest Services, and the news media.

Reports at the workshop covered: the causative agents; the extent of the problem, economics and research needs; what is now being done and future plans; accomplishment barriers; and case studies. The differing points of view of private industry, forestry services, and National Parks from both countries were reported at the workshop. The workshop ended with a field trip through one of the oldest ongoing epidemics in British Columbia.

As a result of the workshop, a memorandum of understanding is being prepared between the two countries to further the cooperation at all levels in dealing with the problems related to mountain pine beetle.

Shrimpton, D. M. and R. W. Reid. 1973. Change in resistance of lodgepole pine to mountain pine beetle between 1965 and 1972. Can. J. For. Res. 3:430-2.

ABSTRACT

In 1965, 100 lodgepole pines (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in each of two areas near Radium, B.C. were graded for resistance to mountain pine beetle (*Dendroctonus ponderosae* Hopk.) by evaluating their response to inoculation with a fungus transported by the mountain pine beetle. In 1972, mortality of these trees due to mountain pine beetle or other causes was determined, trees were inoculated and the resistance of each was again evaluated. Most trees nonresistant in 1965 had been killed by the mountain pine beetle by 1972, whereas most trees rated resistant in 1965 were still alive and were again rated resistant.

Shrimpton, D. M. 1983. Growth characteristics of lodgepole pine associated with the start of mountain pine beetle outbreaks. Can. J. For. Res. 13:137-44.

ABSTRACT

The dynamics of tree and stand growth were studied in six small but expanding mountain pine beetle outbreaks in British Columbia. Stands had exceeded a previously reported hazard threshold of age 80 years by 26 years, and a second frequently used hazard threshold of 20.5 cm mean dbh was exceeded by 37 years. However, stands had exceeded maturity, as defined by the intersection of current annual increment (CAI) and mean annual increment (MAI), by an average of only 17 years. In all cases, the beginnings of the outbreaks were coincident with a period of reduced tree growth. This reduced tree growth was difficult to detect at breast height, with a consequent failure of the periodic growth ratio to indicate susceptibility. Although the stands were past the point of maturity, the dominant and codominant trees continued to add significant wood volume, which could make surveillance for incipient outbreaks and subsequent control actions cost effective.

Shrimpton, D. M. and A. J. Thomson. 1981. Use of physiological maturity to identify hazard of lodgepole pine stands from mountain pine beetle. In R. L. Hedden, S. J. Barras, and J. E. Coster (eds.). Hazard rating systems in forest insect pest management. USDA For. Serv. Gen. Tech. Rept. WO-27, pp. 149-53.

ABSTRACT

From research in our laboratory and a historical review of lodgepole pine (*Pinus contorta* Dougl.) stands sustaining mountain pine beetle (*Dendroctonus ponderosae* Hopk.) outbreaks throughout British Columbia, we proposed that to minimize losses from mountain pine beetle, stands should be managed for wood production and therefore harvested no later than the point when they reach physiological maturity. To test this proposal, we obtained growth data from a grove of lodgepole pine near which mountain pine beetle had been active from 1972 through 1979. Twelve dominant and codominant lodgepole pine were cut from the grove. Results of our examination show that the trees were near physiological maturity; therefore, this aspect of our hazard-rating system was confirmed.

* Silverstein, R. M. 1970. Attractant pheromones of Coleoptera. In M. Beroza (ed.), Chemicals controlling insect behavior. Academic Press, New York, pp. 21-40.

Skorheim, K. T. and D. E. Kistler. 1975. Helicopter removal of trees attacked by mountain pine beetle. Admin. Study, USDA For. Serv., Custer Ranger District, Black Hills NF.

Smith, R. H. 1963. Toxicity of pine resin vapors to three species of *Dendroctonus* bark beetles. J. Econ. Entomol. 56:827-31.

ABSTRACT

The vapor toxicity of saturated resin vapors of both host and non-host pines was determined for three species of *Dendroctonus: D. brevicomis* Le Conte, *D. monticolae* Hopkins, and *D. jeffreyi* Hopkins. Results with hard pines substantiate the hypothesis that bark beetles of this genus can tolerate saturated vapors of host resin but not of non-host resin, suggesting that resin is a determining factor in host specificity. Results with soft pines do not substantiate the hypothesis, suggesting that other properties of resin or non-resinous characteristics of these pines determine host specificity. A delayed effect in many tests with hard pine host resin suggests that even host resins can be deleterious under certain conditions.

Variable results were obtained with hybrid pines. Resin vapors of non-host x non-host hybrids were toxic. *D. brevicomis* and *D. jeffreyi* were usually significantly affected by non-host x host hybrid resin vapors while *D. monticolae* was not.

The overall results suggest that resin in some capacity may be an important factor in host resistance.

Smith, R. H. 1965. A physiological difference among beetles of *Dendroctonus ponderosae* (= *D. monticolae)* and *D. ponderosae* (= *D. jeffreyi).* Ann. Entomol. Soc. Am. 58:440-2.

ABSTRACT

A distinct difference was found between *D. ponderosae* Hopkins (= *monticolae* Hopkins) and *D. ponderosae* (= *jeffreyi* Hopkins) in their reaction to pine resin vapors and their individual components. Practically no difference was found between 2 different host sources of *D. ponderosae* (= *monticolae).* Therefore, the author recognizes a biological difference between *D. ponderosae* (= *monticolae)* and *D. ponderosae* (= *jeffreyi)* and recommends continuing to distinguish between them.

Smith, R. H. 1970. Length of effectiveness of lindane against attacks by *Dendroctonus brevicomis* and *D. ponderosae* in California. J. Econ. Entomol. 63:1180-1.

ABSTRACT

As a 2% diesel oil solution spray, lindane prevented attack by both the western pine beetle, *Dendroctonus brevicomis* LeConte, and the mountain pine beetle, *D. ponderosae* Hopkins, for 36 months; as a 2% aqueous emulsion it was effective for 22 months.

Smith, R. H. 1976. Low concentration of lindane plus induced attraction traps mountain pine beetle. USDA For. Serv. Res. Note PSW-316, 5 pp.

ABSTRACT

Mountain pine beetles were induced to attack lodgepole pine sprayed with 0.2 percent or 0.3 percent lindane emulsion. Large numbers of beetles were killed and fell into traps at the base of the tree. The few successfully attacking beetles caused the sprayed trees to remain attractive to beetles for about two months. The incidence of attacked trees in the immediate area of the sprayed trees was apparently reduced.

Smith, R. H. 1981. Preserving the green sale value of dying ponderosa pine with lindane. USDA For. Serv. Res. Note PSW-350, 3 pp.

ABSTRACT

Pines with dead or dying crowns but without insects or stain in the lower trunk were sprayed in early spring with 1 percent lindane emulsion. The pheromone triplet of the western pine beetle was used to attract the beetle to some of the treated and untreated trees. By late fall 93 percent of the sprayed trees but only 7 percent of the unsprayed trees were still without insect attack or wood stain.

Smith, R. H., J. P. Cramer, and E. J. Carpenter. 1981. New record of introduced hosts for the mountain pine beetle in California. USDA For. Serv. Res. Note PSW-354, 3 pp.

ABSTRACT

In a pine arboretum near Placerville, in northern California, 27 pine species, varieties, or hybrids - many of them introduced species - were attacked by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Among these 27 species, 7 were reported previously as either native or introduced hosts; 5 introduced species or hybrids hitherto unreported as hosts were killed; 5 introduced species or hybrids that were not killed were

classified as probable hosts; and 10 species or hybrids were classified as only possible hosts. These results provide a basis for review and possible revision of the taxonomy of the mountain pine beetle.

Smith, R. H., G. C. Trostle and W. F. McCambridge. 1977. Protective spray tests on three species of bark beetles. J. Econ. Entomol. 70:119-25.

ABSTRACT

In an early extensive series of tests 2% oil solution or aqueous emulsion of lindane or chlorpyrifos, or 2% oil or water suspension of carbaryl prevented both attracted and forced attacks by *Dendroctonus brevicomis* LeConte, *D. ponderosae* Hopkins, and *D. adjunctus* Blandford on *Pinus ponderosa* Lawson and attacks by *D. ponderosae* on *P. contorta* Douglas. The period of effectiveness varied from 3 to more than 36 months depending on the formulation, insecticide, and type of attack: oil solution > emulsion; lindane > chlorpyrifos > carbaryl; forced attacks > attracted attacks. No marked differences could be found between beetle species in a given location. In a later series of attracted attack tests on ponderosa pine, however, 2% water emulsion of chlorpyrifos was not effective against *D. ponderosae*.

* Stallcup, P. L. 1963. A method for investigating avian predation on the adult Black Hills beetle. M.S. Thesis, Colo. St. Univ., Fort Collins.

Stark, R. W. 1978. The mountain pine beetle symposium aspirations. In A. A. Berryman, G. D. Amman, W. R. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 3-5.

ABSTRACT

The evolution of the symposium from a cooperative research project, an integrated pest management program involving the USDA Forest Service, the University of Idaho and Washington State University, is presented. The purpose of the symposium was to present a comprehensive state-of-the-art compendium on the current status of integrated management of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) for critical review by the users-forest managers. The aspiration of the contributors is to synthesize our current knowledge to provide a sound basis for implementation of management practices for regulation of destructive populations of the mountain pine beetle.

Stark, R. W., P. R. Miller, F. W. Cobb, Jr., D. L. Wood and J. R. Parmeter, Jr. 1968. Incidence of bark beetle infestation in injured trees. Hilgardia 39:121-6.

Steiner, G. 1932. Some nemic parasites and associates of the mountain pine beetle *(Dendroctonus monticolae)*. J. Agr. Res. 45:437-44.

Stevens, R. E., D. B. Cahill, C. K. Lister, and G. E. Metcalf. 1974. Timing cacodylic acid treatments for control of mountain pine beetles in infested ponderosa pines. USDA For. Serv. Res. Note RM-262, 4 pp.

ABSTRACT

Careful timing is critical to success in post-attack use of cacodylic acid against mountain pine beetles. Acid must be introduced into infested trees before any larval galleries exceed 0.5 inch in length to achieve satisfactory beetle mortality. Since the beetle attack period may last more than 1 month, more than one visit per area will be necessary to locate and properly treat all the trees that become infested.

Stevens, R. E. and J. C. Mitchell. 1970. Lindane spray effective against mountain pine beetle in the Rocky Mountains. USDA For. Serv. Res. Note RM-167, 4 pp.

ABSTRACT

Lindane-diesel oil solution killed mountain pine beetle *(Dendroctonus ponderosae* Hopk.) in ponderosa pines *(Pinus ponderosa* Laws.) just as effectively as the commonly used insecticide, ethylene dibromide, but takes only 10 percent as much total spray.

Stevens, R. E., C. A. Myers, W. F. McCambridge, G. L. Downing and J. G. Laut. 1974. Mountain pine beetle in Front Range ponderosa pine: What it's doing and how to control it. USDA For. Serv. Gen. Tech. Rept. RM-7, 3 pp.

ABSTRACT

Mountain pine beetle is currently in outbreak status in Rocky Mountains ponderosa pine stands. Much of the cause is probably related to the presence of extensive areas of susceptible forest.

What to do about it depends on the objectives of the landowners or land managers. Combined programs using all suitable control methods are proposed.

Stevens, R. E., W. F. McCambridge and C. B. Edminster. Risk rating guide for mountain pine beetle in Black Hills ponderosa pine. USDA For. Serv. Res. Note RM-385, 2 pp.

ABSTRACT

Average tree diameter, stand density, and stand structure are key elements used in the rating. Single-storied stands are most susceptible to heavy mountain pine beetle damage. Risk increases with d.b.h., reaching a maximum when trees are 12 inches d.b.h. and larger. During buildup of an outbreak, denser stands within a given mean diameter are more susceptible to invasion.

* Stewart, J. L. 1964. Black Hills beetle. Paper presented to the Black Hills Chapt. SAF, Jan. 31, 1964.

Stipe, L. 1975. Trends of a mountain pine beetle infestation in a high elevation stand in Yellowstone National Park. USDA For. Serv., Ogden, UT, 2 pp.

Stipe, L. E. 1976. Trends of a mountain pine beetle outbreak in a high elevation stand in Yellowstone National Park. USDA For. Serv., Ogden, UT, 4 pp.

Stock, M. W. and G. D. Amman. 1980. Genetic differentiation among mountain pine beetle populations from lodgepole pine and ponderosa pine in northeast Utah. Ann. Entomol. Soc. Am. 73:472-8.

ABSTRACT

Isozyme comparisons were made among mountain pine beetles (*Dendroctonus ponderosae* Hopkins) from 4 sites in NE Utah. Genetic differentiation was more closely associated with host tree species - lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) vs. ponderosa pine (*P. ponderosa* Lawson) - than with geographic distances among sites. Differences in average heterozygosity and frequencies at certain gene

loci may be related to stages in the infestation cycle or environmental stress related to food quantity. Differences were small between males and females at any one site but among sites males showed greater differences than did females. A difference in gene frequencies between early-and late-emerging beetles was found at one site.

Stock, M. W., G. D. Amman and P. K. Higby. 1984. Genetic variation among mountain pine beetle *(Dendroctonus ponderosae)* (Coleoptera:Scolytidae) populations from seven western states. Ann. Entomol. Soc. Am. 77:760-4.

ABSTRACT

Genetic characteristics of mountain pine beetles from 15 sites in seven western states were compared using electrophoresis. A high level of genetic similarity was observed among all groups, including those from areas previously considered separate ranges of *D. monticolae* (= *ponderosae)* and *D. ponderosae*.

Stock, M. W. and J. D. Guenther. 1979. Isozyme variation among mountain pine beetle *(Dendroctonus ponderosae)* populations in the Pacific Northwest. Env. Entomol. 8:889-93.

ABSTRACT

To examine genetic variation among mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), populations in the Pacific Northwest, beetles from 6 localities were assayed for isozyme variation using starch gel electrophoresis. Greater genetic differences were observed among males in many samples than among the females. A cline in gene frequencies at the aspartate aminotransferase locus corresponded to north-south geographic distribution of beetle populations in Idaho. Similarity coefficients calculated between all possible pairs of populations indicated the presence of 2 major population units. The largest differences between populations appear to be attributable to long-term geographic isolation.

Stock, M. W., J. D. Guenther and G. B. Pitman. 1978. Implications of genetic differences between mountain pine beetle populations to integrated pest management. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 197-201.

ABSTRACT

Electrophoresis was used to evaluate genetic diversity among mountain pine beetle (*Dendroctonus ponderosae* Hopkins) populations in relation to geographic location and host trees. Populations attacking lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) in pure and mixed stands, western white pine (*P. monticola* Douglas) mixed with lodgepole *latifolia*, and lodgepole var. *murrayana* (Greville and Balfour) mixed with ponderosa pine (*P. ponderosa* Lawson) were examined. No genetic differences were detected among populations from stands of pure lodgepole var. *latifolia* or from *latifolia* mixed with ponderosa pine or white pine. In contrast, there was a larger degree of genetic difference observed between mountain pine beetles in lodgepole *murrayana* and all other populations. Further morphological, physiological and behavioral comparisons between mountain pine beetles in lodgepole *latifolia* and *murrayana* may reveal differences which contribute to variations in the insects' response to specific management practices, such as those employing pheromones.

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ABSTRACT

Data accumulated for more than 25 years from old-growth sugar pine stands in central California showed that the mountain pine beetle preferred to attack mature and overmature trees with the most decadent crowns. Analyses included four age groups and eight crown types. Beetle outbreaks in second-growth sugar pine were nondiscriminating between trees. These outbreaks developed during drought when heavy populations were reared in snow-breakage debris.

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ABSTRACT

Three forest disturbance periods, 1973-present, 1922-29, and 1827-46 were determined by aging scars on stems of lodgepole pine trees. All of the scars from the 1970's and 1920's, and most of the scars from the 1820's-40's were determined to be caused by the mountain pine beetle. A few scars from the earliest period may be the result of fire. Diagnostic characteristics of beetle scars are: resemblance to fire scars, pitch tubes, beetle emergence holes, blue stain, beetle galleries, retained bark on the scar face, and an orange or red discoloration around healthy sapwood. Beetle attacks tend to have a northeastern aspect and extend approximately two-thirds around tree boles at breast height.

By recognizing beetle scars it is possible to accurately age previous mountain pine beetle attacks. Many scars which had been thought to be of fire origin are actually caused by the mountain pine beetle.

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ABSTRACT

Of 30.8 dead, standing, pole-size lodgepole pines per acre in southeastern Idaho, 38 percent yielded 35- to 40-foot long poles that met ANSI standards for size and form. Decay prevented the utilization of 12 percent of the trees for poles. Basal decay, responsible for rejecting over 50 percent of the trees, usually could be eliminated by long-butting trees from 4 to 8 feet. Trees dead for 3 years or longer attained an EMC of about 30 percent at 1 foot, and 14 percent at 16 feet, and higher, above the ground.

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ABSTRACT

The external anatomy of the larvae and pupae of a number of species of the genus *Dendroctonus* was studied to determine its value in the classification of the genus. It was found that the larval and pupal characters supported the synonomy proposed in a revision of the genus based on imaginal characters recently published by another worker.

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ABSTRACT

Front Range beetle-killed ponderosa pine wood is suitable for most traditional uses of the species. Differences are: the beetle-killed timber is drier, usually blue-stained, and may contain wood borers and decay. Mechanical properties may be affected.

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ABSTRACT

Logs of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) supporting immature *Dendroctonus ponderosae* Hopkins were maintained under conditions of non-fluctuating temperature and light. The rate of emergence of the adult beetles exhibited a rhythmic, possibly ciradian, emergence pattern. When the temperatures fluctuated the emergence rate was always greatest in higher temperature.

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ABSTRACT

Adults of *Dendroctonus ponderosae* Hopkins were stored at 1°C in 2-mil polyethylene bags containing moistened excelsior. Under these conditions, 85% of the beetles survived after 30 days. Stored adults showed no decrease in fecundity but the percentage of females in their broods increased with storage duration. Handling prior to storage and interruptions in the storage period resulted in a decrease in survival. Female adults survived storage better than males.

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ABSTRACT

Infestation of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), the most important natural factor in management of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) ecosystems, result in a number of management problems. These infestations seriously affect even flow and sustained yield and make the task of converting unmanaged to regulated forests very difficult. The result is chaos to orderly harvest. The beetles, rather than the manager, set priorities and schedule the cut. Infestations without the follow-up of fire or cutting, using an even-aged silviculture, hasten stands toward the climax stage in forest succession. Infestations may affect stand productivity. Too, access by big game, livestock and man may be affected. The effect on water quality and quantity is probably minimal. Infestations affect recreation and esthetics, build up high fire hazards, and may increase infections of dwarf mistletoe (*Arceuthobium americanum* Nuttall ex Engelmann). Infestations create difficult utilization problems and cause special problems in areas closed to timber harvest. Because of the proclivity of the mountain pine beetle for large-diameter trees, management of lodgepole pine for timber production may face a disappointing future.

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ABSTRACT

The physical association between *Dendroctonus ponderosae* Hopk. and its associated blue stain fungi *Ceratocystis montia* Rumb. and *Europhium clavigerum* Robinson and Davidson and the yeasts *Pichia pini* (Holst) Phaff, *Hansenula capsulata* Wickerham, and *H. holstii* Wickerham is described in single broods reared in bolts of lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm. Eggs just prior to hatch and first-instar larvae were always in contact with the microorganisms whereas newly laid eggs, second-, third-, and fourth-instar larvae were not. During pupation, blue stain fungi and yeasts colonized pupal chamber walls. Transfer of these microorganisms to the new generation of insects was ensured when tenerals contacted the microorganisms lining the pupal chamber. Ensured physical contact between these organisms supports the hypothesis of a symbiosis between them.

Whitney, H. S. and S. H. Farris. 1970. Maxillary mycangium in the mountain pine beetle. Science 167:54-5.

ABSTRACT

A mycangium containing blue-stain fungi and yeasts is located in the cardo of the maxilla of the mountain pine beetle, *Dendroctonus ponderosae* Hopk. Symbiosis between one or more of the microorganisms and the insect is indicated.

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ABSTRACT

Improvements in the rearing methods for axenic mountain pine beetles were made by standardizing the nutritional and physical composition of a yeast-fortified ground phloem diet. By eliminating handling and possible malnutrition of neonate larvae, and by use of individual rearing units to reduce hazards associated with microbial contamination, one person produced batches of 400-500 axenic beetles. Beetles produced by this method were morphologically and anatomically equivalent to and more fecund than field beetles, were significantly smaller than their parental stocks, and perhaps required more degree hours above 40°C in developing from egg to adult.

Whitney, H. S., L. Safranyik, S. J. Muraro and E. D. A. Dyer. 1978. In defense of the concept of direct control of mountain pine beetle populations in lodgepole pine: some modern approaches. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. sta., Univ. of Idaho, Moscow, pp. 159-64.

ABSTRACT

The strategy and tactics of direct control of the mountain pine beetle *(Dendroctonus ponderosae* Hopkins) are reviewed and the absolute requirement for detection of incipient infestations and diligence in treatment application is reiterated. Modern approaches to the use of explosives, the entomopathogenic fungus *Beauveria bassiana* (Balsam) Vuillemin, improvements in standing single tree burning, a mechanical debarker and microwave power are described. The current and future needs for direct control are discussed.

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ABSTRACT

A mountain pine beetle outbreak, probably a result of stand stagnation, resulted in an apparent loss of over 35 years growth in a young ponderosa pine stand. The beetle-caused mortality is probably correlated linearly with the degree of over-stocking. The beetles may have reduced the value of the stand (projected to an age of 140 years) by as much as $265 per acre in some locations. Precommercial thinning would probably have greatly reduced these losses, as well as resulting in an increased growth rate.

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